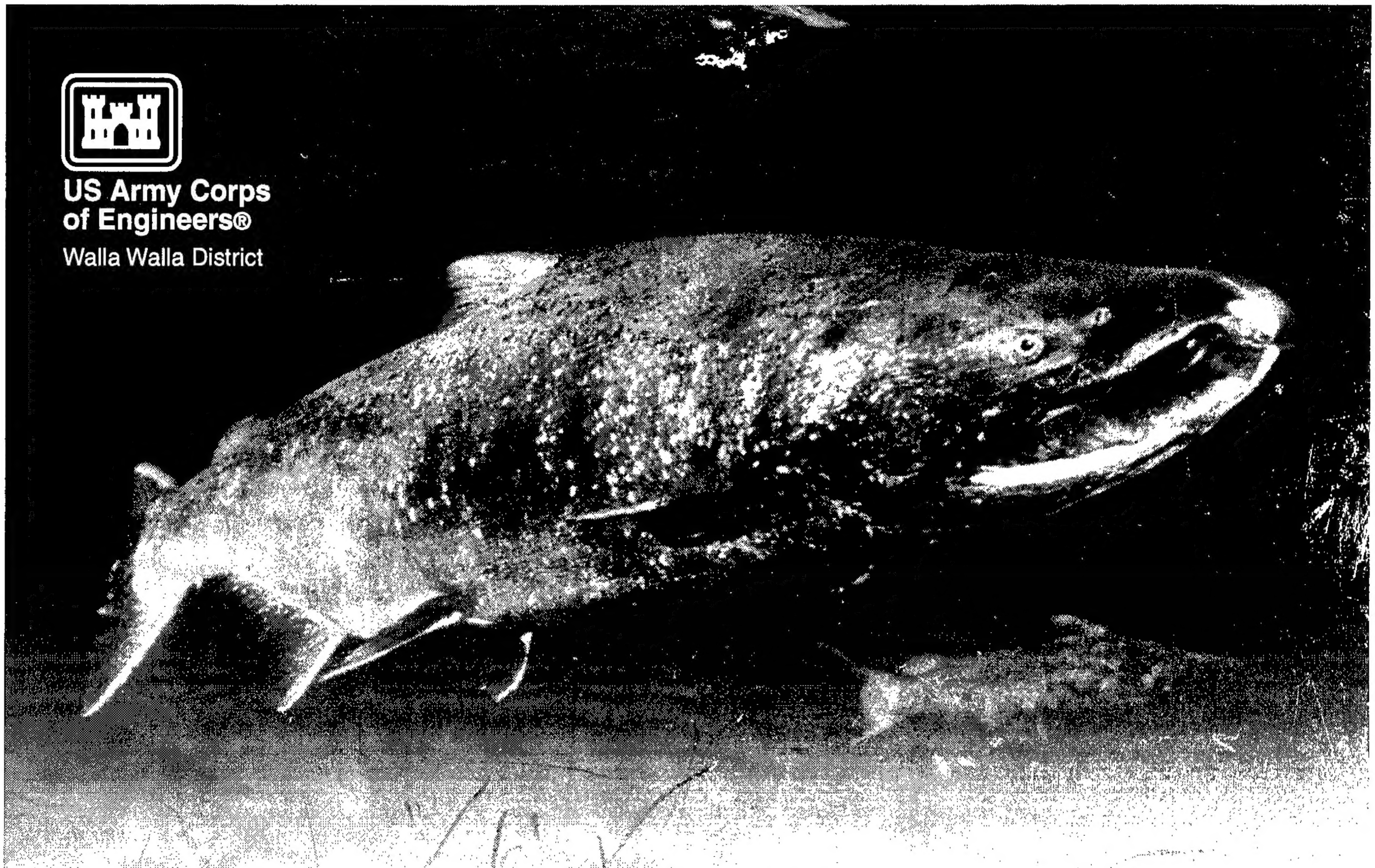

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Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

APPENDIX M
Fish and Wildlife Coordination Act Report

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December 1999

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The Corps of Engineers along with the Bonneville Power Administration, US Environmental Protection Agency, and US Bureau of Reclamation as cooperating agencies, analyzed four general alternatives intended to provide information on the technical, environmental, and economic effects of actions related to improving juvenile salmon passage. The four alternatives include Alternative 1 - Existing Conditions (the no-action alternative) and three different ways to further improve juvenile salmon passage. The action alternatives are: Alternative 2 - Maximum Transport of Juvenile Salmon, Alternative 3 - Major System Improvements, and Alternative 4 - Dam Breaching. Comparison of the alternatives by all of the factors assessed in the study has not offered a clear-cut recommendation at this time. It is the Corps of Engineer's intent to recommend a preferred plan of action in the Final FR/EIS.

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FEASIBILITY STUDY DOCUMENTATION

Document Title	
Summary to the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement	
Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement	
Appendix A	Anadromous Fish
Appendix B	Resident Fish
Appendix C	Water Quality
Appendix D	Natural River Drawdown Engineering
Appendix E	Existing Systems and Major System Improvements Engineering
Appendix F	Hydrology/Hydraulics and Sedimentation
Appendix G	Hydroregulations
Appendix H	Fluvial Geomorphology
Appendix I	Economics
Appendix J	Plan Formulation
Appendix K	Real Estate
Appendix L	Lower Snake River Mitigation History and Status
Appendix M	Fish and Wildlife Coordination Act Report
Appendix N	Cultural Resources
Appendix O	Public Outreach Program
Appendix P	Air Quality
Appendix Q	Tribal Consultation/Coordination
Appendix R	Historical Perspectives
Appendix S	Snake River Maps
Appendix T	Biological Assessment
Appendix U	Clean Water Act. Section 404(b)(1) Evaluation

The documents listed above. as well as supporting technical reports and other study information. are available on our website at www.nww.usace.army.mil. Copies of these documents are also available for public review at various city, county, and regional libraries.

FOREWORD

This appendix is the United States Fish and Wildlife Service's Fish and Wildlife Coordination Act Report (CAR), December 1999. The CAR report has been reformatted for consistency with other appendices. This appendix is one part of the overall effort of the U.S. Army Corps of Engineers (Corps) to prepare the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS).

Please note that this document is a DRAFT appendix and is subject to change and/or revision based on information received through comments, hearings, workshops, etc. After the comment period ends and hearings are concluded, a Final FR/EIS with Appendices is planned.

The Corps has reached out to other regional stakeholders (Federal agencies, tribes, states, local governmental entities, organizations, and individuals) during the development of the FR/EIS and Appendices. This effort resulted in many of these regional stakeholders providing input, comments, and even drafting work products or portions of these documents. This regional input provided the Corps with an insight and perspective not found in previous processes. A great deal of this information was subsequently included in the Draft FR/EIS and Appendices; therefore, not all the opinions and/or findings herein may reflect the official policy or position of the Corps.

STUDY OVERVIEW

Purpose and Need

Between 1991 and 1997, due to declines in abundance, the National Marine Fisheries Service (NMFS) made the following listings of Snake River salmon or steelhead under the Endangered Species Act (ESA) as amended:

- sockeye salmon (listed as endangered in 1991)
- spring/summer chinook salmon (listed as threatened in 1992)
- fall chinook salmon (listed as threatened in 1992)
- steelhead (listed as threatened in 1997)

In 1995, NMFS issued a Biological Opinion on operations of the Federal Columbia River Power System. The Biological Opinion established measures to halt and reverse the declines of these listed species. This created the need to evaluate the feasibility, design, and engineering work for these measures.

The U.S. Army Corps of Engineers (Corps) implemented a study after NMFS's Biological Opinion in 1995 of alternatives associated with lower Snake River dams and reservoirs. This study was named the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). The specific purpose and need of the Feasibility Study is to evaluate and screen structural alternatives that may increase survival of juvenile anadromous fish through the Lower Snake River Project (which includes the four lower dams operated by the Corps on the Snake River—Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams) and assist in their recovery.

Development of Alternatives

The Corps completed an interim report on the Feasibility Study in December 1996. The report evaluated the feasibility of drawdown to natural river levels, spillway crest, and other improvements to existing fish passage facilities. Based in part on a screening of actions conducted in the interim report, the study now focuses on four courses of action:

- Existing conditions (currently planned fish programs)
- System improvements with maximum collection and transport of juveniles (without major system improvements such as surface bypass collectors)
- System improvements with maximum collection and transport of juveniles (with major system improvements such as surface bypass collectors)
- Dam breaching or permanent drawdown to natural river levels for all reservoirs

The results of these evaluations are presented in the combined Feasibility Report (FR) and Environmental Impact Statement (EIS). The FR/EIS provides the support for recommendations that will be made regarding decisions on future actions on the Lower Snake River Project for passage of juvenile salmonids. This appendix is a part of the FR/EIS.

Geographic Scope

The geographic area covered by the FR/EIS generally encompasses the 140-mile long lower Snake River reach between Lewiston, *Idaho* and the Tri-Cities in Washington. The study area does slightly

vary by resource area in the FR/EIS because the affected resources have widely varying spatial characteristics throughout the lower Snake River system. For example, socioeconomic effects of a permanent drawdown could be felt throughout the whole Columbia River Basin region with the most effects taking place in the counties of southwest Washington. In contrast, effects on vegetation along the reservoirs would be confined to much smaller areas.

Identification of Alternatives

Since 1995, numerous alternatives have been identified and evaluated. Over time, the alternatives have been assigned numbers and letters that serve as unique identifiers. However, different study groups have sometimes used slightly different numbering or lettering schemes and this has lead to some confusion when viewing all the work products prepared during this long period. The primary alternatives that are carried forward in the FR/EIS currently involve four major alternatives that were derived out of three major pathways. The four alternatives are:

Alternative Name	PATH[1/] Number	Corps Number	FR/EIS Number
Existing Conditions	A-1	A-1	1
Maximum Transport of Juvenile Salmon	A-2	A-2a	2
Major System Improvements	A-2'	A-2c	3
Dam Breaching	A-3	A-3a	4

[1/] Plan for Analyzing and Testing Hypotheses

Summary of Alternatives

The **Existing Conditions Alternative** consists of continuing the fish passage facilities and project operations that were in place or under development at the time this Feasibility Study was initiated. The existing programs and plans underway would continue. Project operations, including all ancillary facilities such as fish hatcheries and Habitat Management Units (HMUs) under the Lower Snake River Fish and Wildlife Compensation Plan (Comp Plan), recreation facilities, power generation, navigation, and irrigation would remain the same unless modified through future actions. Adult and juvenile fish passage facilities would continue to operate.

The **Maximum Transport of Juvenile Salmon Alternative** would include all of the existing or planned structural and operational configurations from the Existing Conditions Alternative. However, this alternative assumes that the juvenile fishway systems would be operated to maximize fish transport from Lower Granite, Little Goose, and Lower Monumental and that voluntary spill would not be used to bypass fish through the spillways (except at Ice Harbor). To accommodate this maximization of transport some measures would be taken to upgrade and improve fish handling facilities.

The **Major System Improvements Alternative** would provide additional improvements to what is considered under the Existing Conditions Alternative. These improvements would be focused on using surface bypass collection (SBC) facilities in conjunction with extended submersible bar screens (ESBS) and a behavioral guidance system (BGS). The intent of these facilities is to provide more

effective diversion of juvenile fish away from the turbines. Under this alternative the number of fish collected and delivered to upgraded transportation facilities would be maximized at Lower Granite, the most upstream dam, where up to 90 percent of the fish would be collected and transported.

The **Dam Breaching Alternative** has been referred to as the "Drawdown Alternative" in many of the study groups since late 1996 and the resulting FR/EIS reports. These two terms essentially refer to the same set of actions. Because the term drawdown can refer to many types of drawdown, the term dam breaching was created to describe the action behind the alternative. The Dam Breaching Alternative would involve significant structural modifications at the four lower Snake River dams allowing the reservoirs to be drained and resulting in a free-flowing river that would remain unimpounded. Dam breaching would involve removing the earthen embankment sections of the four dams and then developing a channel around the powerhouses, spillways, and navigation locks. With dam breaching, the navigation locks would no longer be operational, and navigation for large commercial vessels would be eliminated. Some recreation facilities would close while others would be modified and new facilities could be built in the future. The operation and maintenance of fish hatcheries and Habitat Management Units (HMUs) would also change although the extent of change would probably be small and is not known at this time. Project development, design, and construction span a period of nine years. The first three to four years concentrate on the engineering and design processes. The embankments of the four dams are breached during two construction seasons at year 4-5 in the process. Construction work dealing with mitigation and restoration of various facilities adjacent to the reservoirs follows dam breaching for three to four years.

Authority

The four Corps dams of the lower Snake River were constructed and are operated and maintained under laws that may be grouped into three categories: 1) laws initially authorizing construction of the project, 2) laws specific to the project passed subsequent to construction, and 3) laws that generally apply to all Corps reservoirs.

BOUNDARIES

State

County

KM 300 100 0

MILES 7.5 15 30

125,000 ACRES

1 : 1,900,800

GEOGRAPHIC INFORMATION SYSTEMS

Corps of Engineers Walla Walla District

DRAFT

Lower Snake River

Juvenile Salmon Migration Feasibility Study

REGIONAL BASE MAP

1999

GIS Analysts & Graphic Assembly: Applied Technology Team (CENWW-PM-PD-EI)
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ABSTRACT

This document was prepared by the U.S. Fish and Wildlife Service (USFWS). This Fish and Wildlife Coordination Act Report (FWCAR) is Appendix M to the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement by the U.S. Army Corps of Engineers (Corps). The FWCAR was prepared by individuals from several USFWS offices and was coordinated from the Moses Lake Ecological Services office. While the Corps' Feasibility Study is concerned with anadromous fish, the FWCAR addresses both anadromous and resident fish, as well as wildlife resources, pursuant to the Fish and Wildlife Coordination Act. The FWCAR addresses fish and wildlife resources present before the reservoirs were constructed, those present now, and the projected beneficial and adverse effects to these resources from implementing each of the Corps' four alternatives. It includes a preliminary recommendation of the four alternatives as well as recommendations for such things as mitigation measures, monitoring, enhancement measures, and additional studies needed.

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Draft

Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

Appendix M

Fish and Wildlife Coordination Act Report

Produced by

U.S. Fish and Wildlife Service

Produced for

U.S. Army Corps of Engineers

Walla Walla District

Completed December 1999
Revised and released for review
with Draft FR/EIS
December 1999

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ACRONYMS AND ABBREVIATIONS

AFG	perennial forb and grasses
all Hs	harvest, hatcheries, habitat, and hydropower
BGS	behavioral guidance structure
BOR	Bureau of Reclamation
BPA	Bonneville Power Authority
CBFWA	Columbia Basin Fish and Wildlife Authority
cfs	cubic feet per second
Comp Plan	Lower Snake River Fish and Wildlife Compensation Plan
Corps	U.S. Army Corps of Engineers
CRRL	Columbia River Research Laboratory
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESU	evolutionarily significant unit
Feasibility Study	Lower Snake River Juvenile Salmon Migration Feasibility Study
FERC	Federal Energy Regulatory Commission
flip lips	flow detectors
FPC	Fish Passage Center
FWCAR	Fish and Wildlife Coordination Act Report
GBT	gas bubble trauma
GIS	geographic information system
HEP	habitat evaluation procedures
HIS	habitat suitability index
HMU	habitat management unit
HSIs	habitat values
HU	habitat unit
IDFG	Idaho Department of Fish and Game
ISAB	Independent Scientific Advisory Board
ISG	Independent Science Group
kcfs	thousand cubic feet per second
LGS	Lower Granite South
LOA	Letter of Agreement
MAF	million acre-feet
MOP	minimum operating pool
NEPA	National Environmental Policy Act
NFH	National Fish Hatchery
NMFS	National Marine Fisheries Service
NPPC	Northwest Power Planning Council
NTMB	neotropical migratory bird
OHWL	ordinary high water line
PATH	Plan for Analyzing and Testing Hypothesis
PCB	polychlorinated biphenyl
PIT	passive integrated transponder
PNNL	Pacific Northwest National Laboratory

ACRONYMS AND ABBREVIATIONS

ppm	parts per million
SAR	smolt-to-adult return
SBC	surface bypass collector
SWI	simulated Wells Dam intake
TAC	Technical Advisory Committee
TDG	total dissolved gas
TMT	Technical Management Team
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington [State] Department of Ecology
WNHP	Washington Natural Heritage Program

Executive Summary

Despite considerable expense and efforts, anadromous fish stocks in the Snake River Basin continue to decline. On March 2, 1995, the National Marine Fisheries Service (NMFS) issued a Biological Opinion on the Operation of the Federal Columbia River Power System and Juvenile Transportation Program, in accordance with the Endangered Species Act (ESA). This Biological Opinion identified several necessary measures for survival and recovery of Snake River salmon stocks listed under the Endangered Species Act. One of the responsibilities of the Corps of Engineers (Corps) was to conduct a study on measures associated with their facilities which influence migration through the hydrosystem. The Corps' Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study) was to evaluate measures that may increase survival of juvenile anadromous fish migrating through the lower Snake River. They narrowed an array of alternative actions down to four primary alternatives: Existing Systems, Maximum Transport, Surface Bypass/Collection, and Natural River Drawdown.

A large number of studies and analyses were conducted and are still being conducted to evaluate the appropriateness (benefits and costs) of the four alternatives, with many of the results to be included in the Corps Feasibility Study/ Environmental Impact Statement (EIS). Some of the areas covered include hydropower, irrigation, transportation, and other economic issues (both project-specific and regional); cultural resources; recreation; water quality and sedimentation; resident fish; terrestrial resources; and, of course, anadromous fish. The results of the analyses covering these areas, along with other factors, will all play into the decision-making process for the selection and implementation of a preferred alternative by the Corps.

One of the tools the Corps must use for decision-making for water resources projects is coordination with the U.S. Fish and Wildlife Service (USFWS), in accordance with the Fish and Wildlife Coordination Act (FWCA). This Act provides that fish and wildlife conservation must receive equal consideration with other project features. It also requires that the USFWS investigations be made an integral part of the Corps report to Congress. In this case, the USFWS investigations are presented in a Fish and Wildlife Coordination Act Report (FWCAR) and will be attached to the EIS as an appendix. The FWCA states that one purpose of coordination with the USFWS is to determine means and measures to prevent the loss of or damage to fish and wildlife resources, as well as to provide concurrently for the improvement of such resources. The USFWS has done this in this draft FWCAR through the development of mitigation and enhancement measures and recommendations.

The FWCAR examines pre-dam and current conditions for fish and wildlife resources and then looks at potential beneficial and adverse effects from implementing various alternatives within the scope and context of the Corps Feasibility Study. A major limitation of the Corps Feasibility Study is that it did not examine the four primary alternatives in the context of all of the human activities that have affected listed salmon and steelhead which are often referred to as all Hs (that is, harvest, hatcheries, habitat, and hydropower). A number of technical efforts are underway to assess the impact of human-induced factors on declining salmonid populations and the potential effect of actions for recovery of those populations. These are works in progress that will provide additional information on the recovery of listed salmonids in the broader context of all Hs. We intend to include additional information in the final FWCAR to evaluate the four alternatives within the broader context of all Hs, and we will provide our final recommendations at that time.

In the interim, we have completed our evaluation within the scope of the EIS of the potential beneficial and adverse effects for fish and wildlife resources resulting from implementing the various alternatives. It is clear in our assessment that the Natural River Drawdown Alternative would provide many more benefits to fish and wildlife than the other three alternatives in the area of the four lower Snake River dams. Also, we believe the Drawdown Alternative would best increase survival of juvenile anadromous fish migrating through the area of the four lower Snake River dams. Additionally, it would significantly increase the area of spawning and rearing habitat for Snake River fall chinook, a threatened species. Furthermore, it is the only alternative that addresses restoration of natural or near natural riverine conditions which would produce a myriad of positive influences on natural processes and fish and wildlife. Therefore, based on our biological evaluation of the four alternatives effects on fish and terrestrial resources, the USFWS concludes that the benefits to fish and wildlife from the Natural River Drawdown Alternative exceed the benefits provided by the other alternatives.

Alternatives

The four main alternatives being considered in the Feasibility Study include Existing Systems (No Action), Maximum Transport, Surface Bypass/Collection, and Natural River Drawdown. The Existing Systems Alternative would continue operation of the lower Snake River dams and reservoirs under NMFS's 1995 biological opinion on operation of the federal Columbia River power system and the juvenile transportation program (NMFS, 1995, Biological Opinion). This would include both transporting a portion of the juvenile fish and leaving a portion to migrate in the river. Some planned improvements include juvenile fish facility improvements at Lower Granite Dam, extended screens at Little Goose and Lower Granite dams, and flow deflectors at Ice Harbor Dam. The Maximum Transport Alternative is essentially the Existing Systems Alternative with a focus on limiting in-river migration of juvenile salmonids. This would be accomplished by limiting spill and transporting fish collected in facilities by trucks or barges rather than bypassing them below the dams.

Surface Bypass/Collection is being considered as another alternative for improving juvenile salmonid survival during passage through the lower Snake River. A prototype of this concept has been tested at Lower Granite Dam since 1996. In theory, Surface Bypass/Collection would divert juvenile salmonids in the surface waters of the project forebays and bypass them without depth and pressure changes now associated with conventional screen and bypass systems.

Permanent drawdown of the lower Snake River reservoirs is the fourth major alternative under consideration. The Natural River Drawdown Alternative considers drawdown to a near natural river condition with various flow augmentation scenarios. Drawdown would be accomplished by the removing the earthfill portions of each of the four dams.

Pre-dam Resources

Anadromous fish

Anadromous fish utilized the mainstem Snake River and its tributaries for spawning, rearing, and as a migration route. Anadromous salmonids that were present included spring, summer, and fall races of chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), sockeye salmon (*Oncorhynchus nerka*), and steelhead (*Oncorhynchus mykiss*). Other anadromous fishes that inhabited the Snake River System included white sturgeon (*Acipenser transmontanus*) and Pacific lamprey (*Lampetra tridentata*). Before construction of the four lower Snake River dams and the

Hells Canyon dam complex, the Snake River System was one of the major producers of anadromous fish in the Columbia River Basin.

Resident fish

Information on resident fish historically present in the lower Snake River is very limited. However, northern pikeminnow (*Ptychocheilus oregonenis*) and suckers (*Catostomus* sp.) comprised a significant portion of the native cultures fish diet in certain areas. Also, white sturgeon were well-dispersed throughout the Columbia River Basin from the estuary at the mouth of the river, up the Snake River to southern Idaho, and well into the Kootenai drainage of Canada and Montana. It is assumed that the lower Snake River resident fish community was comprised primarily of native riverine-adapted species. However, many non-native species were introduced into the Columbia River Basin by the turn of the twentieth century.

Terrestrial resources

The majority of the study area is within the grassland and shrub-steppe ecotypes. Also, a riparian zone was present along the Snake River and was very important to fish and wildlife species. Much of the study area had been adversely affected by land use practices, such as grazing and farming, before construction of the lower Snake River dams. However, remaining native habitats still provided important habitat to many wildlife species, especially the riparian areas. Although riparian habitat had also been affected by various land use practices, about 1,335.5 hectares (ha) (3,300 acres) of woody riparian habitat was present before any dam construction.

Post-dam Resources

Anadromous fish

Habitat for anadromous salmonids has been greatly altered by the dams and reservoirs in the lower Snake River. Dams have disrupted the continuum of high-quality habitat, leaving little riverine habitat in the lower Snake River and isolating other habitats. A major change has been the inundation of productive riverine habitat. Another result of the dams has been creation of artificial flow, thermal, and sediment regimes. Also, the dams and reservoirs have had major effects on migrating anadromous fish. Juvenile salmonids now have difficulty making it through the reservoirs and past the dams in a safe and timely manner. Delayed seaward migration of smolts exposes them to higher water temperatures, decreased flows, and levels of predation not experienced before the dams were built. Also, adult salmonid migration may be affected at dams, especially during periods of high flow when they have difficulty finding fish ladder entrances or fall back after passing the dams. Extremely high levels of dissolved gas caused by forced or uncontrolled spill at the dams during high flow periods can be detrimental to both juvenile and adult salmonids.

Naturally produced spring, summer, and fall chinook salmon, sockeye salmon, and steelhead continue to use the Snake River and its accessible tributaries, although their abundance has declined drastically. Sockeye salmon have been reduced to a remnant population that is close to extinction. Snake River coho salmon were declared extinct, but other stocks have been reintroduced in an attempt to re-establish a population. Hatchery production has helped to maintain the adult returns of some anadromous salmonids, such as steelhead. However, wild fish production has continued to decline, and Snake River steelhead, spring/summer chinook, and fall chinook have been listed as threatened species by NMFS.

Resident fish

The lower Snake River reservoirs currently support a diverse fish fauna; however, their construction drastically altered the ecosystem of the Snake River. The once dynamic riverine environment, subject to a wide range of spring floods, has become a series of controlled impoundments. Reduced current velocities, changes in bottom substrate, lowered dissolved oxygen, and changes in water temperatures have favored cool and warmwater resident fish species, many of which are not native to the Snake River. High-quality stream fisheries for smallmouth bass (*Micropterus dolomieui*), white sturgeon, and channel catfish (*Ictalurus punctatus*) in the lower Snake River have been converted to a low-quality reservoir-type fishery with abundant populations of non-game species. Cold-water resident species, such as rainbow trout (*Oncorhynchus mykiss*) and mountain whitefish (*Prosopium williamsoni*), once common in the Snake River, have declined since construction of the dams.

Several species of resident fish present in the lower Snake River reservoirs prey on salmonid smolts as they migrate toward the ocean. However, predation is not considered a major source of mortality for salmon smolts in this stretch of the lower Snake River. An exception is juvenile fall chinook, whose unique life history increases vulnerability to predation.

Invertebrates

Benthic diversity in the lower Snake River reservoirs is relatively low and is dominated by midges and worms. The density of other taxa such as amphipods (*Corophium* sp.) and nematodes is also low. Mollusc diversity has also been greatly reduced by the impoundment of the Snake River. However, crayfish appear to be well established throughout the lower Snake River reservoirs and provide an important food source for several species.

Terrestrial resources

About 745 ha (1,840 acres) of woody riparian habitat existed along the lower Snake River in 1997, which is about 55 percent of that present before inundation. Irrigated plantings on habitat management units (HMUs) accounted for about 202 ha (500 acres) of the woody riparian habitat, and the remainder was from plantings on other facility lands, habitat already present after inundation, and natural revegetation along the shorelines. However, the species composition has changed from pre-dam conditions. For example, Russian olive (*Elaeagnus angustifolia*) is now the dominant tree species. Also, riparian habitat quality has not returned to pre-dam conditions, despite the Corps spending considerable dollars and efforts to recreate riparian habitat.

Habitat values estimated for existing conditions for some wildlife species were much lower than those estimated for pre-facility conditions. Much of this difference appears to be from slow development of woody vegetation at these facilities and poor species and structural diversity. Additionally, Canada goose (*Branta canadensis*) habitat declined because of the inundation of nesting islands. River otter (*Lutra canadensis*) habitat at the upper facilities increased after the dams, probably from improved denning habitat from extensive riprap. Grassland and shrub-steppe habitat has improved for the upper reaches of the study area with grazing elimination.

At this point, compensation exceeds losses from reservoir inundation for 7 of the 12 species modeled using Habitat Evaluation Procedures (HEP); however, nearly one third of the quantified losses remain uncompensated. All of the species with uncompensated losses are either dependent on or prefer riparian/wetland habitat for some life requisite. The irrigated HMUs have not fully replaced lost riparian habitat values because (1) HMUs often incorporate non-native species which are inferior to

native habitats for many wildlife species (2) HMUs are usually distinct habitat islands with little if any connectivity to other similar habitats. This can limit dispersal, genetic mixing, and expose individuals to increased predation risk when moving between habitats.

Environmental contaminants

Environmental contaminants have been detected in low concentrations in some sediments within the study area; however, additional sampling needs to be done to better determine contaminant concentrations and distribution.

Future with Existing Systems Alternative

The Existing Systems Alternative would continue the ongoing program with planned structural improvements and operations according to NMFS's 1995 Biological Opinion and 1998 supplement. Some improvement in juvenile and adult fish passage would occur, but conditions that lead to passage problems at the dams and through reservoirs would continue.

Anadromous fish

- Controlled spill at dams in the spring and transportation of fish during the summer would be required for juvenile fish migration.
- Flow augmentation would continue to be required with existing volumes or increased volumes of water. Summer drawdown of Dworshak Reservoir would continue, as would summer flow augmentation from Upper Snake River and Hells Canyon facilities.
- Existing losses of fish during their passage through the lower Snake River would continue or be slightly reduced with planned structural improvements.
- Continued operation and maintenance of passage facilities for adult and juvenile fish would be required.
- Lower Snake River Fish and Wildlife Compensation Plan (Comp Plan) fish hatcheries and associated facilities and operations would continue to be required in the foreseeable future and would continue to fail to meet mitigation goals.
- Lamprey passage needs would not be addressed. Water quality conditions would remain the same unless measures to improve contributing factors are implemented.

Adult and juvenile salmonids migrating in the spring would be exposed to extremely high and potentially lethal levels of gas supersaturation caused by uncontrolled spill, such as could occur during the spring freshet.

The water temperature regime in the lower Snake River would improve little unless temperature control were provided at the Hells Canyon facilities.

Resident fish

- Native fish species would continue to prefer the >more riverine segments of the reservoirs, such as the tailraces immediately below the dams and the old river channels; as reservoirs age, these areas would become more limited.
- White sturgeon would continue to face passage problems at the four dams, continuing an artificial partial segregation of this population.

- Non-native species would continue to use the warmer, slower, backwater areas created along the margins of the reservoirs.
- Northern pikeminnow, smallmouth bass, and channel catfish would continue to be significant predators of juvenile fall chinook salmon.
- Gas supersaturation during spill would continue to affect resident fish species, perhaps adversely.
- The resident fish mitigation goal for construction of the four lower Snake River dams was replacement of 67,500 angler days. This is accomplished by stocking 39,009.6 kg (86,000 lbs) of catchable rainbow trout annually, is considered successful, and would need to continue.
- Anglers fishing the lower Snake River reservoirs overwhelmingly prefer steelhead, but of those seeking resident fish, channel catfish, smallmouth bass, and rainbow trout would remain the preferred species.
- Resident fish sport harvest would continue to be dominated by crappies, smallmouth bass, channel catfish, and rainbow trout.
- Invertebrate fauna, although currently high in biomass, would continue to have little diversity and would be dominated by worms, midges, and crayfish.
- The threat of a zebra mussel invasion would be likely. They could clog fish passageways and their sharp edges would injure and descale smolts that come in contact with them.

Terrestrial resources

- This alternative would have no measurable effect on wildlife species. By the same token, it would not provide the opportunity for any benefits to these resources.
- Riparian corridors would continue to be disjunct and dominated with non-native species, mainly in artificial islands maintained with irrigation.
- Intensive management efforts would continue to maintain wildlife habitat and food plots in limited areas.
- Size and structural complexity of riparian vegetation would continue to develop slowly.
- Mitigation for wildlife losses from the construction of the four dams would continue to remain at about 75 percent of the estimated losses.

Future with Maximum Transport of Juvenile Salmon Alternative

This alternative would seek to collect and transport as many juvenile salmonids as possible from the Lower Monumental, Little Goose, and Lower Granite dams and to release them in the lower Columbia River downstream from Bonneville Dam.

Anadromous fish

The effect of this alternative on the survival and recovery of Snake River anadromous fish would be similar to the effect of the Existing Systems Alternative with the following additions.

Maximum transport would result in a slight increase in the number of juvenile salmonids that are transported. The overall effect of this increase would depend on the survival of transported fish.

- Presently, there is uncertainty about the relative survival of transported fish compared to those that are not transported.
- Analyses by NMFS and PATH indicate that the Natural River Drawdown Alternative has a greater probability of recovery and survival for spring/summer chinook, steelhead, and fall chinook than the Maximum Transport Alternative.

Resident fish

This alternative would have little or no effect on resident fish species, resident sport fishing, and invertebrates. All bullets listed for the Existing Systems Alternative for resident fish and invertebrates apply to this alternative as well.

Terrestrial resources

This alternative would have no measurable effect on wildlife species. All bullets listed for the Existing Systems Alternative for wildlife apply to this alternative as well.

Future with Surface Bypass/Collection Alternative

The surface bypass/collection system at Lower Granite Dam is a prototype of a concept that is still being tested. It could potentially meet juvenile salmon fish passage efficiency goals for the region if it attained the performance of the surface bypass at Wells Dam.

Anadromous fish

- Studies to date indicate that the Surface Bypass/Collection prototype alone has not met the Wells Dam surface bypass performance or fish passage efficiency goals.
- Studies on the prototype will not be completed until 2000.
- Existing study information indicates that Surface Bypass/Collection would require:
  - Continued use of the existing screen and fish bypass system and the behavioral guidance system (steel curtain) to successfully divert juvenile salmonids
  - The use of existing screen and fish collection facilities plus spill to meet fish passage efficiency goals
  - Substantial reduction of the volume of water after diversion by the surface collector if fish are to be directed into a bypass system for transportation [No agreement exists in the region that this can be technologically accomplished.]
- If feasible, surface collection may take several years to become operational to meet regional standards. For example, the Wells Dam surface bypass required 12 years to become successful.
- This alternative does not address migration of lamprey.
- Structural and operational features of the Existing Systems Alternative would still be required.
- Uncontrolled spill at the lower Snake River dams during high flow periods would continue to produce excessively high total dissolved gas levels.

Resident fish

This alternative would have little or no effect on resident fish species, resident sport fishing, and invertebrates. All bullets listed for the Existing Systems Alternative for resident fish and invertebrates apply to this alternative as well.

Terrestrial resources

This alternative would have no measurable effect on wildlife species. All bullets listed for the Existing Systems Alternative for wildlife apply to this alternative as well.

Future with Natural River Drawdown Alternative

Ecosystem restoration

Natural river drawdown would allow the re-establishment of a riverine environment along over 225 km (140 miles) of the lower Snake River. While it would not address all problems with Snake River salmon and steelhead stocks, it would restore near natural or normative ecosystem processes, and associated benefits, on a landscape scale. The Corps (Technical Appendix H) found that since the lower Snake River was a partially alluvial system that was characterized by armored cobble/gravel bed material and areas of bedrock, it would be reasonable to assume that pre-dam bathymetry approximates what would occur in the long term following dam breaching (Corps, 1999). Therefore, the physical condition of the river channel (channel morphology) should be able to return to a near natural condition, with differences occurring at small scales.

- While flows originating in the upper Snake River Basin and the North Fork Clearwater would still be controlled by dam operations at Hells Canyon Complex and Dworshak dams, a major portion of the basin would become completely unregulated, allowing natural rhythms of spring runoff to occur.
- A more natural flow regime would help maintain and restore the timing, variability, and duration of floodplain inundation and associated benefits for wetlands and other habitats.
- A network of complex and interconnected habitats would be re-established, including:
  - A variety of aquatic habitats
  - A functional floodplain
  - Restored physical integrity of aquatic systems, i.e., shorelines, banks, and bottom configurations
  - A properly functioning riparian zone with native vegetation, providing food and habitat for many aquatic and terrestrial species and improving water quality.
- Water temperature regimes would improve with a riverine system.
- A riverine-based high-quality food supply, to which native aquatic organisms have been adapted, would be restored.

While restoration of more natural flow and temperature regimes in the lower Snake River would immediately follow drawdown, restoration of other ecosystem components and processes would take several years to several decades. Some effort would be needed to ensure that natural processes could function as naturally as possible, but delineating specific habitat parameters and creating artificial habitat should not be necessary. For example, sinuosity of the stream and pool to riffle ratios should

be dictated by river geomorphology, surrounding terrain, and weather patterns. This system should be self-maintaining once established.

Anadromous fish

Short-term effects

- Short-term effects could be adverse, but they could be mitigated.
- Resuspended sediment and high turbidity immediately following dam breaching may cause direct mortality of anadromous fish and sedimentation may adversely affect existing fall chinook redds (likely 10 or less). Impacts could be mitigated by timing work to occur in the winter when the fewest fish are present.
- Adult fish migration would be blocked by drawdown work. Blockage could be reduced by timing work to occur when the fewest fish are present.
- Adult fish entry into tributaries would be blocked during drawdown until streams eroded a channel through their deltas to the Snake River. Mitigation would involve monitoring drawdown operations and excavating stream channels where necessary.
- Fish could be stranded or entrapped during drawdown operations. Impacts could be mitigated by conducting drawdown when the fewest fish were present, minimizing drawdown rate, monitoring for stranding, and salvaging stranded fish.

Long-term effects

- Adult salmon and steelhead would have unhindered migration through the lower Snake River.
- Breaching could eliminate the few fall chinook redds that now occur in the tailraces of Lower Granite, Little Goose, and Lower Monumental dams; however, up to 1,437 ha (3,550 acres) of fall chinook spawning habitat could be restored.
- Juvenile salmonids would have unimpeded migration through the lower Snake River, shortening travel times and increasing their survival.
- Improved migration conditions for migratory fish could reduce or eliminate the need to augment streamflows in the lower Snake River.
- This is the only alternative with promise for improving juvenile survival enough for Comp Plan mitigation compensation goals to be realized.
- Riverine rearing habitat for juvenile fall chinook salmon would be restored in the lower Snake River. About 312 ha (770 acres) of preferred rearing habitat and about 257 km (160 lineal miles) of suitable shoreline habitat could be provided.
- Injury and mortality caused by passage through the existing screen and bypass systems or the turbines would be eliminated.
- Riverine conditions would provide a more complex environment of riffles, pools, and rapids, increasing the diversity of aquatic invertebrate food items.
- Natural river drawdown would allow for unimpeded migration by lamprey.
- Natural river drawdown would improve at least some aspects of water quality in the lower Snake River in the long term.

- Spill and its accompanying high total dissolved gas (TDG) levels would no longer occur, and safer conditions for fish and other aquatic life would be present.
- A free-flowing river would dissipate gas-supersaturated water produced by uncontrolled spilling at Hells Canyon and Dworshak dams.
- Free-flowing river conditions could increase the ability to meet temperature standards in the lower Snake River through releases from Dworshak Dam.
  - Currently, it is unknown how contaminants in sediments, which would be resuspended and redeposited following drawdown, would potentially affect aquatic life. While some sediment samples have contained detectable levels of a few environmental contaminants, additional investigations would be needed to better determine the extent of contaminants in the sediments, their bioavailability to aquatic organisms, and the potential adverse impacts, if any, they may pose to aquatic organisms.

Resident fish

<u>Short-term effects</u>

- The most significant short-term effect of drawdown to both resident fish and invertebrates is the potential for stranding. Mitigation would involve monitoring fish stranding and initiating rescue attempts where numbers warrant the effort.
  - Most resident fish would be able to follow receding water levels; however, some fish would be stranded as pockets of water became isolated from the main channel. Juvenile fish, especially non-native fish that rear in the backwater areas, would be more likely to become stranded than adults.
  - Those invertebrate species that would avoid desiccation by burrowing deeper into the substrate and those that would move too slowly to follow receding water levels would be lost.
- The loss of shallow, backwater areas would result in the loss of preferred spawning habitat for many non-native resident fish species.

<u>Long-term effects</u>

- Most native resident fish species would benefit from returning the lower Snake River to a free-flowing river since most are broadcast spawners and depend on flowing water for successful reproduction.
  - White sturgeon sub-populations would no longer be artificially isolated and numbers would increase due to improved spawning and rearing habitat and increased food abundance.
  - Usage of the area by species that prefer cold water, such as bull trout, mountain whitefish, and rainbow trout, would increase as connectivity between tributaries improved and water temperatures were cooler for prolonged periods.
  - Redside shiners, chiselmouth, peamouth, sculpin, and bridgelip suckers would benefit.
  - Largescale suckers are habitat generalists and would decrease in abundance due to the loss of aquatic habitat associated with drawdown.

- Most non-native species would decrease in abundance from loss of their preferred shallow areas with little to no current and soft substrate.
- Predation by resident fish species on listed stocks of fall chinook would decrease because 1) increased flow velocity would reduce predator/prey encounters; 2) associated increased turbidities would reduce effectiveness of predators that rely on sight; 3) earlier cooling of water temperature would decrease predator metabolism and effectiveness; and, 4) dam structures that currently give northern pikeminnow an advantage would be gone.
- Resident fish sport fishing would improve since populations of smallmouth bass, rainbow trout, and white sturgeon would increase in abundance and channel catfish populations would remain about the same.
- The ongoing rainbow trout mitigation program could be stopped when a properly functioning ecosystem was reestablished.
- Invertebrate species diversity would increase dramatically:
  - Overall abundance of worms and midges would decrease.
  - Drift from the Snake River and major tributaries would provide a rich source of colonizers for the newly created flowing habitat.
  - Numbers of mayflies, caddis flies, and stone flies would increase.
  - Mollusc diversity would increase with molluscs currently persisting in the Hells Canyon Reach of the Snake River re-inhabiting areas downstream once cooler, faster water provided more suitable habitat than that which currently exists.
  - Crayfish density would likely be similar or better than current conditions.

Terrestrial resources

Short-term Effects

- Extensive foraging areas for several shorebird species would be created as water levels receded with the drawdown.
- A significant amount of riparian habitat would be lost (dessication and separation from waters edge) and converted to upland habitats.
- Some wildlife would be lost through direct mortality (for example, smaller and less mobile species such as small mammals and amphibians would not survive the short-term loss of riparian and wetland habitats).
- Some wildlife would be lost through indirect mortality (for example, some wildlife would be exposed to predation when traveling from cover to the waters edge; more mobile species may attempt to disperse to nearby habitats which are already at or near carrying capacity; and the travel/migration corridor along the river may be reduced even further than that existing now.).
- There would be an opportunity for several weed species to spread rapidly along the river on exposed mud flats. The proposed implementation of aggressive revegetation and weed control measures would mitigate this impact.

Long-term Effects

Our analysis assumes the Corps would actively manage their lands following drawdown to ensure restoration of a near natural ecosystem is as complete as possible and would include such things as an aggressive weed control plan and revegetation measures being applied immediately following drawdown. It also assumes the Corps would continue to irrigate and manage current HMUs until riparian and buffer vegetation is well established (about 25 years).

- The riparian zone present before the dams were constructed (about 1,335.5 ha [3,300 acres] of woody riparian habitat) would be restored.
- The quality and quantity of riparian habitat would likely be increased to a level above that which existed immediately before the dams were constructed, since sediments deposited in the reservoirs (much of it rich topsoil) would provide an excellent substrate for plant growth.
- Improved riparian habitat conditions would result in positive effects for several groups of wildlife (game birds, raptors, other non-game birds, big game animals, small mammals, and bats).
- Improved habitat conditions would also benefit some species of waterfowl, furbearers, amphibians, and reptiles.
- Full mitigation for wildlife losses that occurred when the dams were constructed, mitigation for interim losses, and mitigation for wildlife losses associated with the Drawdown Alternative should all be easily attained.
- Most of the existing wetlands (about 121 ha [300 acres]) would be lost with a reduction or elimination of species that rely on them.
- Additional wetlands should develop in the new floodplain as well as in the McNary pool from sedimentation following the drawdown.
- There would be a loss of reservoir habitats and reduction or elimination of species that rely on them (for example, some waterfowl and gull species).

Conclusions

As noted throughout this draft report, there would be both beneficial and adverse effects to anadromous and resident fish and terrestrial resources from the various alternatives. In general, the Existing Systems, Maximum Transport and Surface Bypass/Collection Alternatives would have very little effect, if any, on resident fish or terrestrial resources. However, the Natural River Drawdown Alternative would result in major changes to much of the lower Snake River and would significantly affect all species groups. The benefits to fish and wildlife resources in the area of the four lower Snake River dams from drawdown would exceed those provided by the other alternatives.

It is unlikely that the Existing Systems Alternative could improve existing conditions for migrating anadromous salmonids. Past operation of the existing system has been accompanied by a downward trend in wild Snake River salmon and steelhead. Furthermore, this alternative does not address lamprey or white sturgeon passage needs and would not benefit resident fish or terrestrial resources.

The Maximum Transport Alternative would increase the percentage of juvenile salmonids collected from the lower Snake River and transported to the lower Columbia River compared to existing operations under NMFS's 1995 and 1998 biological opinions. This increase would likely be moderate because the portion of juvenile fish that is now collected and transported is already

relatively high. The Maximum Transport Alternative potentially could increase the benefits as well as the disadvantages of transportation. The major benefit would be reduced mortality of juvenile fish during transit from the lower Snake River to the release point downstream from Bonneville Dam. Adverse effects could include increased straying of returning adult fish that were transported as juveniles, increased stress, and greater delayed mortality. This alternative does not address lamprey or white sturgeon passage needs and would not benefit resident fish or terrestrial resources.

The Surface Bypass/Collection Alternative involves a prototype of a concept that is still being tested. Studies to date have not shown that it has met fish passage efficiency goals and Surface Bypass cannot achieve high fish passage efficiencies alone. This alternative would need existing or improved fish screen and bypass systems. Also, Surface Bypass/Collection would not improve migration rates or survival of juvenile salmonids in the reservoirs. Finally, this alternative is not likely to improve lamprey or sturgeon migration and would not affect resident fish or terrestrial resources.

The Natural River Drawdown Alternative would restore near natural or normative riverine ecosystem conditions to over 225 km (140 miles) of the lower Snake River. Some initial measures may be needed to help restore these conditions, while much of the restoration and maintenance of these conditions would occur naturally. Also, once established, this system would virtually maintain itself and would need little human assistance in the future, similar to the free-flowing Hells Canyon Reach of the Snake River.

The Natural River Drawdown Alternative would improve migration conditions for anadromous salmonids and other migratory fish through the area of the four lower Snake River dams, restore riverine habitat and spawning habitat for fall chinook salmon, and improve water quality. Returning the lower Snake River to a free-flowing river would benefit most resident fish native to the area, while species introduced to the system and that have capitalized on the reservoir habitat would decrease in abundance. Other non-native species that typically do well in river environments, such as smallmouth bass and channel catfish, would likely either increase or not be greatly affected. Overall, sportfishing in the study area would be enhanced. With the restoration of a functioning riparian zone and floodplain, habitat critical for many wildlife species would develop and be maintained in the long term.

While breaching the lower Snake River dams would have some short-term adverse impacts to fish and wildlife resources, the long-term benefits would far outweigh the potential impacts. Also, some of the potential adverse impacts could be mitigated. The FWCAR includes several mitigation, monitoring, and enhancement recommendations. These would help ensure that adverse impacts are avoided, minimized, and compensated and that conditions are monitored to facilitate adaptive management.

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1. Introduction

Although considerable expense and effort have been aimed at improving anadromous fish passage on the Columbia and Snake rivers, while also attempting to halt salmon declines with habitat improvements, hatcheries, harvest regulations, predator control programs, etc., anadromous fish stocks in the Snake River Basin have continued to decline. On March 2, 1995, the National Marine Fisheries Service (NMFS) issued a biological opinion, in accordance with the Endangered Species Act (ESA) of 1973, as amended, for the "Reinitiation of Consultation on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program in 1995 and Future Years" (NMFS 1995 Biological Opinion) (NMFS, 1995a). This biological opinion established certain measures deemed necessary for the survival and recovery of listed Snake River salmon stocks. The NMFS 1995 Biological Opinion also established a decision path for the implementation of long-term alternatives. The first decision point occurred in 1996 and resulted in the Corps of Engineers' (Corps) December 1996 Interim Status Report on the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). Therefore, the Feasibility Study is being driven primarily by listed threatened and endangered anadromous fish covered in the NMFS 1995 Biological Opinion.

The Interim Status Report evaluated several drawdown alternatives for the four lower Snake River dams, surface bypass/collection, and current fish programs to determine the best configuration to safely pass juvenile salmon in the lower Snake River. The report concluded that there was insufficient information at that time on which to base a sound decision and recommended continuing investigation of only the following three alternatives: (1) permanent drawdown to near natural river level for all four facilities, (2) surface bypass/collection, and (3) the current fish programs. In addition, the Corps is evaluating a maximum transport alternative. The next decision point will be in 2000, when a final plan for drawdown or surface bypass/collection will be selected, and the National Environmental Policy Act (NEPA) documentation will be completed.

Although the Feasibility Study is being driven primarily by listed anadromous fish under ESA, the Corps must also consider other fish and wildlife resources in accordance with other laws such as the Fish and Wildlife Coordination Act (48 Stat. 401, as amended, 16 U.S.C. 661 et seq.). Under the authority of this Act, a 1997 letter of agreement between the Corps and the U.S. Fish and Wildlife Service (USFWS), and, scopes of work for 1997, 1998, and 1999, the Corps has asked USFWS to provide a Fish and Wildlife Coordination Act Report (FWCAR) for the Feasibility Study. This FWCAR addresses wildlife and both anadromous and resident fish resources present before the reservoirs were constructed, those present now, and the projected beneficial and adverse effects to these resources from implementing each of the four alternatives. It also provides a variety of recommendations for such things as mitigation measures, monitoring, and additional studies needed. The Corps would use information contained in the FWCAR to help preserve, mitigate, compensate, or enhance fish and wildlife resources that may be affected by the proposed Lower Snake River Project alternatives. They would also use this information in their environmental impact statement (EIS) required for NEPA compliance for the Feasibility Study.

In addition to the FWCAR, anadromous fish concerns are being addressed by NMFS in Technical Appendix A of the EIS (Corps, 1999). This appendix only addresses anadromous fish species listed under the ESA and is supposed to use information from the multi-agency scientific PATH (Plan for Analyzing and Testing Hypotheses) process. Additionally, their analysis is supposed to be more quantified; whereas, the FWCAR analysis of anadromous fish concerns is more qualitative.

Furthermore, the FWCAR deals with various aspects of previous, existing, and future anadromous fish habitat, while the NMFS report does not. In short, the NMFS Anadromous Fish Report (Appendix A) and the FWCAR were intended to complement each other, with little overlap of information.

Information for this report was gained from several site visits; background experience and knowledge of the authors; Service and Corps reports, files, maps and aerial photographs; personal communications with other agency and tribal personnel, researchers, and other knowledgeable individuals; and published literature. The Biological Resources Division of the U.S. Geological Survey (USGS) provided the geographic information system (GIS) services and produced most figures for this report. We intend to include additional information in the final FWCAR to evaluate the four alternatives within the broader context of all Hs, and we will provide our final recommendations at that time.

2. Study Area

The Snake River drains an area of about 282,310 square kilometers (109,000 square miles), including portions of Idaho, northwestern Wyoming, northern Utah and Nevada, southeastern Washington, and eastern Oregon (Figure 2-1). Major tributaries downstream of Hells Canyon Dam include the Salmon, Grand Ronde, Imnaha, Clearwater, Tucannon, and Palouse rivers. The Snake River flows through a canyon of varying depths from about 1,676 m (5,500 feet) in upstream Hells Canyon to less than 104 m (340 feet) near its confluence with the Columbia River.

The study area boundary includes all the Corps' project lands along the lower Snake River from Ice Harbor Dam, near the mouth of the Snake River, to the upper reaches of Lower Granite reservoir on the Clearwater and Snake rivers (Figure 2-2). Ice Harbor Dam was the first dam constructed on the lower Snake River and it was completed in 1962. Lower Monumental Dam was completed in 1968, Little Goose Dam in 1970, and Lower Granite Dam in 1975. The dams were authorized by Congress to provide slackwater navigation, irrigation, and hydroelectric generation. The lower Snake River is now four contiguous reservoirs from Ice Harbor Dam to the upper reaches of Lower Granite reservoir, a distance of about 225 km (140 miles).

The four lower Snake River facilities are located within a sparsely populated area, with the largest towns being Lewiston, Idaho, and Clarkston, Washington, at the upper end of Lower Granite reservoir. Most of the land next to the facilities is in private ownership and is used for livestock production, with lesser amounts of irrigated and dryland farming, orchards, and vineyards. Much of the lower Snake River Canyon is generally steep, with basalt bluffs rising up to 610 m (2,000 feet) to rolling uplands. The lower Snake River floodplain was relatively large and still occurs in places such as at the confluence of the Palouse and Tucannon rivers.

Floodplain soil is a combination of silt wash from the surrounding plateau, glacial gravel and sand, and river sand of glacial origin (Lewke and Buss, 1977). Before impoundment, many of the tributary streams formed large alluvial fans.

Aside from inundating a large amount of riparian habitat with the four lower Snake River reservoirs, almost all of the rich alluvial soils in the floodplain were also inundated. This has left shallow, rocky soils along most of the new shoreline. In addition to shallow soils, the steep shorelines, adjacent railroad right-of-ways, and unfavorable water regimes in the reservoirs have limited the amount of riparian vegetation which can develop (USFWS, 1993a).

The Lower Snake River Fish and Wildlife Compensation Plan (Compensation Plan) was developed in 1975 to compensate or mitigate for fish and wildlife losses from constructing the four lower Snake River reservoirs. It included the construction of several fish hatcheries, acquisition of fisherman access sites to replace lost anadromous fishing opportunities, acquisition (in fee-title and lease) of lands and management to replace wildlife values, and release of 20,000 pen-reared gamebirds each year for 20 years to help replace lost hunting opportunities. The Compensation Plan has been amended several times since then. The proposal to release gamebirds was dropped, and more intensive management actions to try and replace lost habitat values have been added. For example, much of the facility lands was fenced to control grazing by livestock, most facility lands were dedicated to wildlife management, additional lands were purchased along the Snake River for wildlife management purposes, active management (including vegetation establishment, irrigation development, construction of watering locations, artificial cover, nesting structures, and several

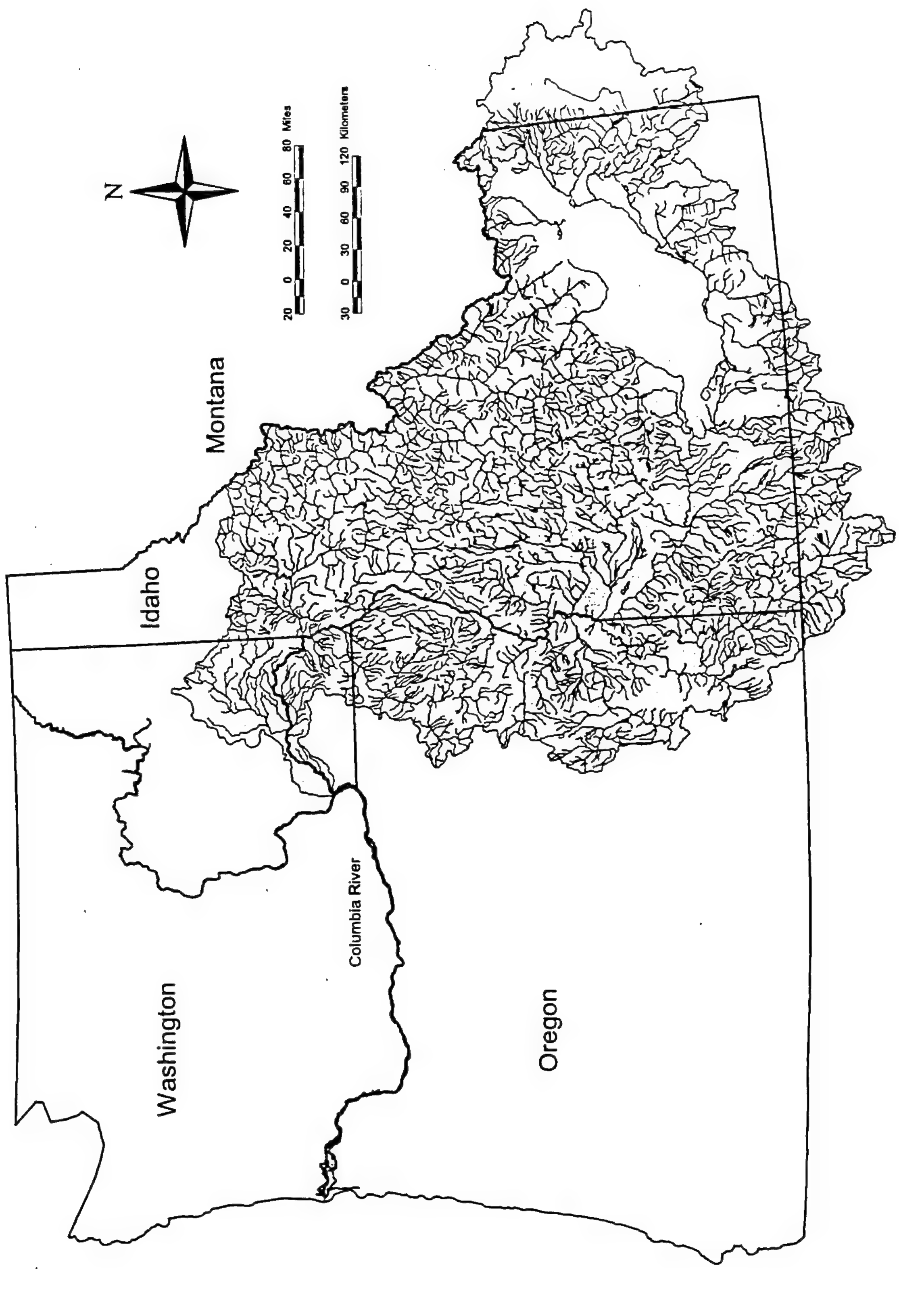

Figure 2-1. The Snake River Basin With Major Tributaries Displayed

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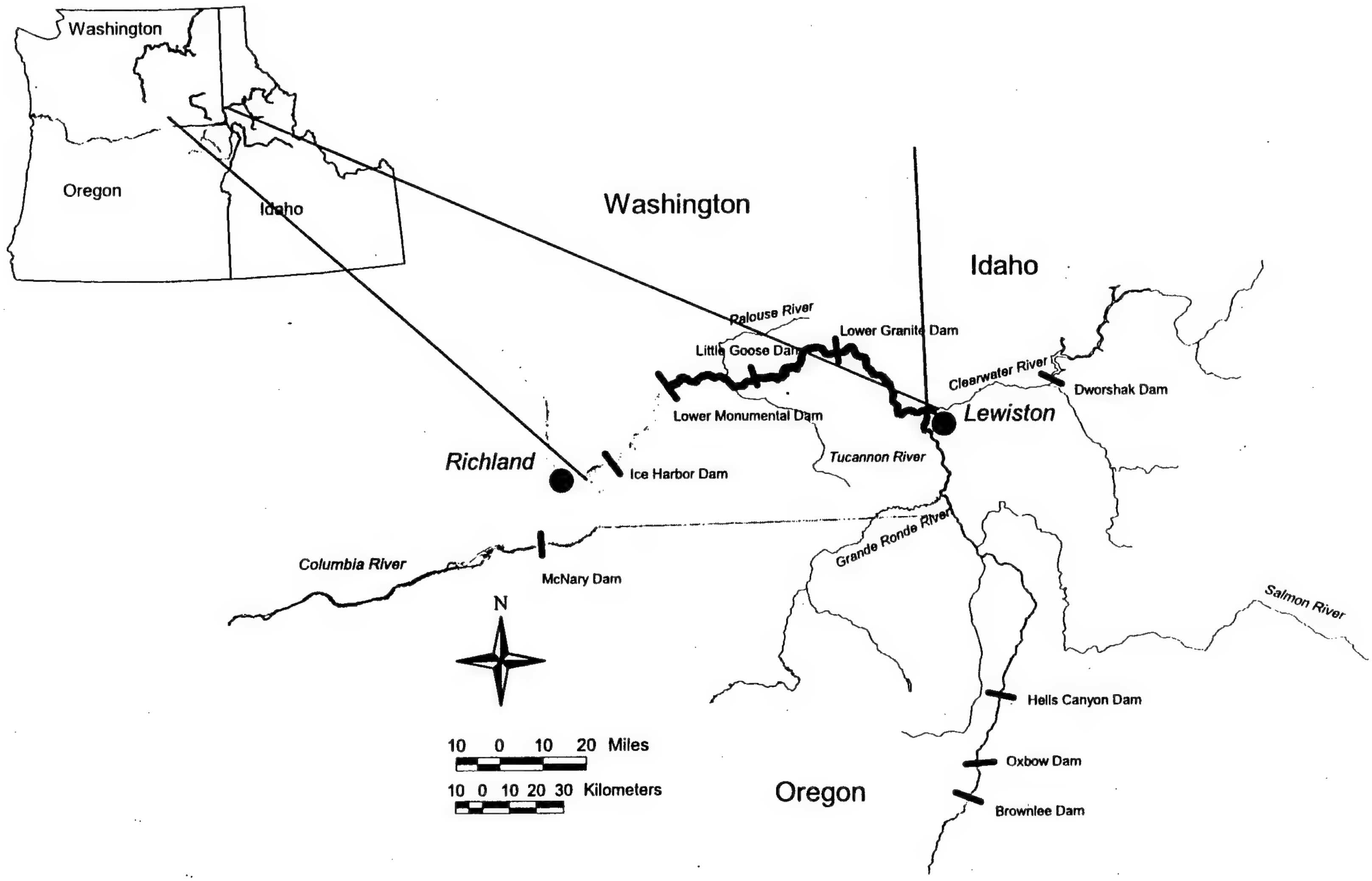

Figure 2-2. The Study Area (shown in bold) Along the Snake River and Locations of the Major Dams and Tributaries to the Snake River

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other actions) was initiated on a portion of the facility lands termed habitat management units (HMUs), land parcels outside of the Snake River canyon were purchased, and active management was initiated on them.

There is a total of nearly 10,401 ha (25,700 acres) of Corps' facility lands associated with the 13,715 ha (33,890 acres) occupied by the four lower Snake River reservoirs. About 1,295 ha (3,200 acres) of these lands are intensively managed HMUs, with more than 405 ha (1,000 acres) currently being irrigated. Much of the remaining facility land is managed more passively for improved wildlife habitat. The Corps purchased an additional 9,712 ha (24,000 acres) of off-facility lands through fee title or easements under the Compensation Plan. These lands are managed by the Corps or the Washington Department of Fish and Wildlife (WDFW) to help compensate for wildlife losses. While lands scattered from along the Grand Ronde River to the Yakima River and up into the agricultural region of the Columbia Basin Irrigation Project have been acquired, the goal has always been to try and replace those wildlife habitat values formerly along the lower Snake River. Off-site lands would not be directly affected by the proposed alternatives and are only discussed in this report as they relate to compensation for lost habitat values.

Lower Granite and Little Goose reservoirs are operated within a 1.5 m (5-foot) water level range while Ice Harbor and Lower Monumental reservoirs operate within a 0.9 m (3-foot) range (Corps, 1993). Since 1990, the Corps has tried to operate these reservoirs near the lower level of this range, which is called the minimum operating pool (MOP), as required under the NMFS 1995 Biological Opinion. MOP starts on April 10 and continues until about late August when adult fall chinook begin to enter the lower Snake River. Operating at lower elevations increases average water velocities through the reservoir, therefore decreasing juvenile salmonid migration time through the lower Snake River system. Slow passage through reservoirs increases the exposures of juvenile anadromous fish to predation, higher temperature, and other water quality problems (NMFS, 1995b). Therefore, increasing water velocities through the reservoirs should hopefully improve juvenile salmonid survival.

3. Project Alternatives

The four main alternatives being considered in the FWCAR include 1) Existing Systems (No Action), 2) Maximum Transport, 3) Surface Bypass/Collection, and 4) Natural River Drawdown. Additional elements have been added to these alternatives and additional alternatives discussed since the initiation of this study. For example, the addition of 80,202.2$^{m^3}$ (1 million acre-foot [MAF]) augmentation flow from the upper Snake River Basin and the drawdown of John Day Reservoir to near natural level are being considered. However, the main focus of this FWCAR will be on the above four alternatives, with a more limited analysis of additional measures being considered.

3.1 Existing Systems Alternative

The Existing Systems Alternative would include the present operation of the lower Snake River dams and reservoirs under the NMFS 1995 Biological Opinion. This would include transporting juvenile fish and allowing them to remain in the river to migrate. It would also include planned improvements such as juvenile fish facility improvements at Lower Granite Dam, extended screens at Little Goose and Lower Granite dams, and flow deflectors at Ice Harbor Dam.

All of the lower Snake River dams have passage facilities for adult fish. Fish passage facilities consist of a fish ladder, with entrances and collection systems, powerhouse collection systems, fish counting stations, and auxiliary water supply systems for attracting fish. Ice Harbor and Lower Monumental dams have two fish ladders, one at each end of the dam. Little Goose and Lower Granite dams have single, south-shore fish ladders. The single ladder facilities also have north-shore fishway entrances, powerhouse collection systems, and channels to transport fish to the fish ladders on the south side of the dams. Fish passage facilities for adult fish are operated according to criteria specified in the Fish Passage Plan for Corps facilities (Corps, 1998). This plan is reviewed and revised annually by a regional group of biologists from the operating agencies, state and Federal fisher-agencies, and tribes.

All lower Snake River dams presently have juvenile fish passage facilities, although the types of structures differ at each facilities. The dams have either standard length submerged traveling screens or extended length bar screens and vertical barrier screens to divert fish from turbine intakes. Also, Lower Granite, Little Goose, and Lower Monumental dams are collector facilities, designed to collect downstream migrating fish for subsequent transport by barge or truck, while juvenile migrants at Ice Harbor Dam are merely bypassed around to the Snake River. The collector facilities are equipped with facilities to sort and separate fish, passive integrated transponder (PIT) (Prentice et al., 1990) tag detectors, raceways for holding fish before transportation, sampling and marking facilities, and barge and truck loading facilities. Figure 3-1 shows a typical juvenile fish screen, collection, and bypass system.

The lower Snake River facilities are presently operated according to the "Reasonable and Prudent Alternatives" measures specified in the NMFS 1995 Biological Opinion and the NMFS 1998 Supplemental Biological Opinion. These biological opinions include numerous operational measures which are currently implemented to improve the survival of juvenile and adult salmon and steelhead. These measures include flow augmentation and temperature control, spill, transport of juvenile fish, maintaining reservoirs at MOP, operating turbines within 1 percent of peak efficiency, and maintaining fishways within criteria specified in the Corps' Fish Passage Plan.

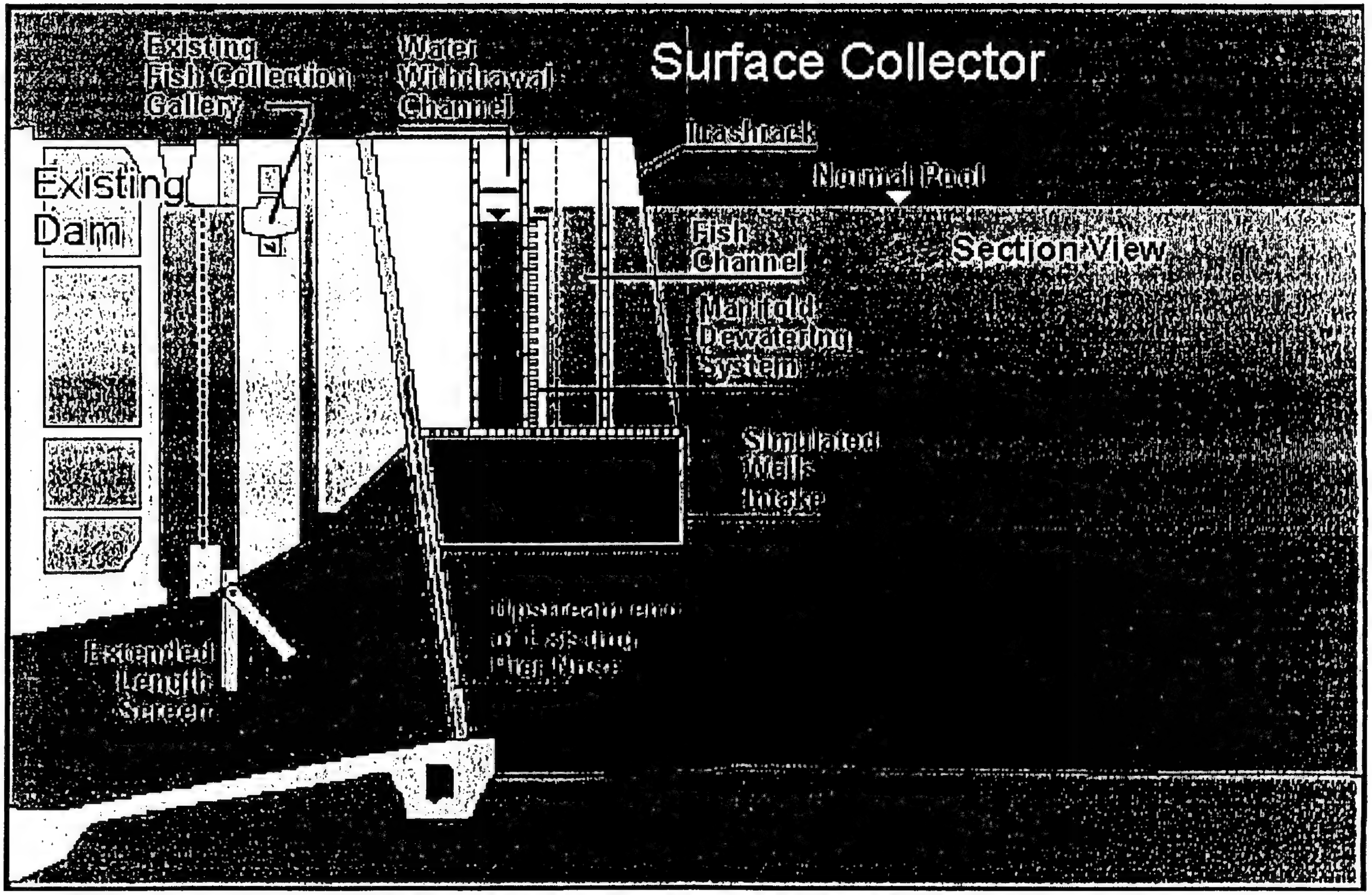

Figure 3-1. Typical Fish Screen, Collection, and Bypass System

In the future, the lower Snake River dams would continue to operate under the requirements of the existing and future biological opinions for listed fish species affected by facility operations. These operations would include planned structural improvements that have been approved within the region and funded by Congress. Examples of such structural improvements include flow deflectors (flip lips) to reduce total dissolved gas (TDG) levels under spill conditions, extended length screens at turbine intakes, and bypass outfall relocation.

The Corps' Columbia River Fish Mitigation Program includes a number of ongoing and planned measures to improve fish passage for juvenile and adult anadromous fish to mitigate the adverse effects caused by the construction and operation of the Federal dams on the mainstem Snake and Columbia rivers.

Continued operation of the lower Snake River dams would require further development of the existing and future structural features that are intended to protect fish at these facilities. The major areas of planned improvements include juvenile fish collection and bypass systems, adult fish passage facilities, dissolved gas abatement, and juvenile fish transportation. Water temperature control may be another required action pending the results of studies being conducted to determine the presence, extent, and location of any water temperature problems in fish ladders.

3.2 Maximum Transport of Juvenile Salmon

This alternative includes all of the existing or planned structural changes for the Existing Systems Alternative as a base. Additionally, this alternative assumes that the juvenile fishway systems would be operated to maximize fish transport and that voluntary spill would not be used to bypass fish through the spillways (except at Ice Harbor) (Corps, 1999). This alternative would focus on limiting in-river migration, and fish collected in facilities would be transported downstream by trucks or barges rather than bypassed below the dams.

3.3 Surface Bypass/Collection Alternative

Surface bypass collection would be considered with and without transportation, with spillway passage, and with gas abatement measures. Installation of a surface bypass collection device at Lower Granite Dam has been proposed as one alternative for improving juvenile salmonid survival during passage through the Snake River (Figure 3-2). Reasonable and Prudent Alternative Measure 11 in the NMFS 1995 Biological Opinion directs the Corps to test a prototype surface bypass collector (SBC) at Lower Granite Dam by 1996 to determine the effectiveness and safety in passing juvenile salmonids. In theory, the SBC would divert juvenile salmonids in the surface waters of the facility forebays and bypass these fish without subjecting them to changes in depth and pressure now associated with conventional screen and bypass systems. This operation assumes that most juvenile salmonids are outmigrating in the surface waters of the dam forebays and that they would be drawn to the surface collector by the collective flows of the turbines and surface collector.

This concept is based on the experience at Wells Dam which has been the most successful surface bypass system in the Columbia River Basin. The Wells Dam surface bypass is a hydrocombine which has the spillgates located directly above the dam turbines. Fish are drawn toward the structure by the collective flows of the turbines and spillgates. At Lower Granite Dam and the other Snake River dams the spillways are located next to the powerhouses. The prototype SBC is an attempt to simulate conditions at Wells Dam by locating the collector above the turbine units to use the combined flow toward the powerhouse and collector to attract juvenile fish. A prototype SBC was installed at Lower Granite Dam in 1996 and was tested during the 1996 and 1997 migration seasons.

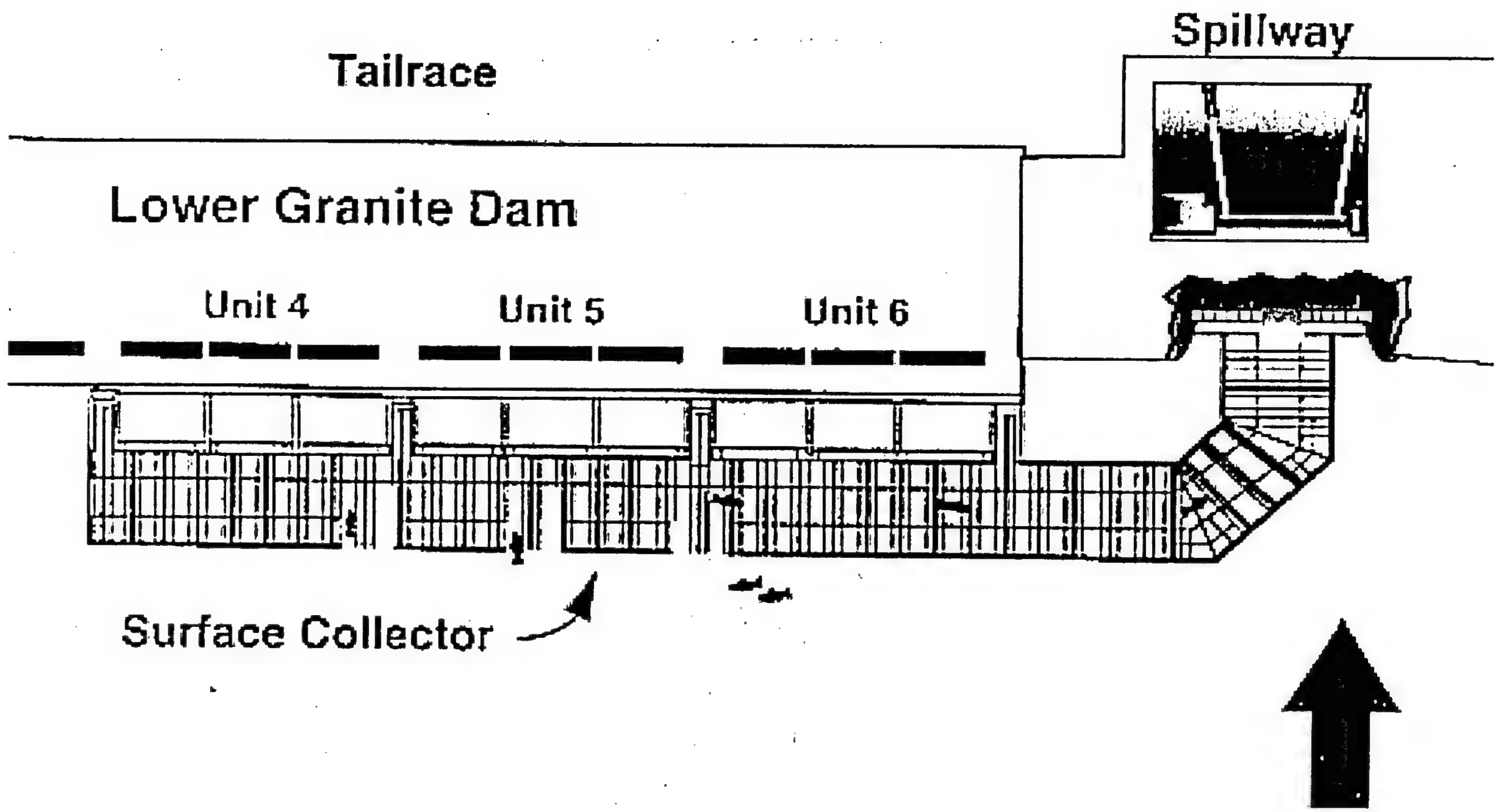

Figure 3-2. Surface Bypass/Collection Device at Lower Granite Dam

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Additional testing and studies were conducted during 1998 using a modified collector and the behavioral guidance structure, a steel wall suspended by floats, which is intended to direct fish toward the SBC and spillway.

In its Retrospective Analysis (PATH, 1996), the PATH group indicated that the existing available information was not sufficient to determine if surface collectors could substantially increase the proportion of Snake River salmon that are transported. PATH indicates that "with extended screens in place at Little Goose and Lower Granite dams, the additional installation of a surface collector at Lower Granite Dam has the potential to increase the total number of smolts transported from the Snake River by about 6 to 13 percent if it is as effective as the surface bypass system at Wells Dam." PATH also stated, however, that the increase in proportion of fish transported would be minimal if the Lower Granite collector is less efficient than the Wells collector (PATH, 1996). Presently, the available information is insufficient to determine the potential efficiency of a surface collector at Lower Granite Dam. PATH also states that it is unlikely that the surface collection system at Lower Granite Dam would be as efficient as the Wells Dam facility because of differences in dam configurations.

3.4 Natural River Drawdown Alternative

Permanent drawdown of the lower Snake River reservoirs to a near natural river condition is the fourth major alternative under consideration. The Natural River Drawdown Alternative would consider drawdown to a near natural river condition with NMFS 1995 Biological Opinion flow augmentation. In addition, we examined the Natural River Drawdown Alternative with some flow augmentation and without flow augmentation. Drawdown would be accomplished by the removal of the earthfill portions of each of the dams down to the original riverbed elevation. Figure 3-3 gives a conceptual view of drawdown. As currently proposed, the drawdown would occur for either two dams at the same time and then for the final two dams in 1 or 2 more years, or for all four dams at the same time. The drawdowns would begin about August and would be completed within 60 to 90 days. These drawdowns would eventually restore the lower Snake River to a riverine condition after accumulated sediments are transported out of the system and into the Columbia River. Figure 3-4 shows how a stretch of the lower Snake River near Little Goose Dam would appear following a natural river drawdown.

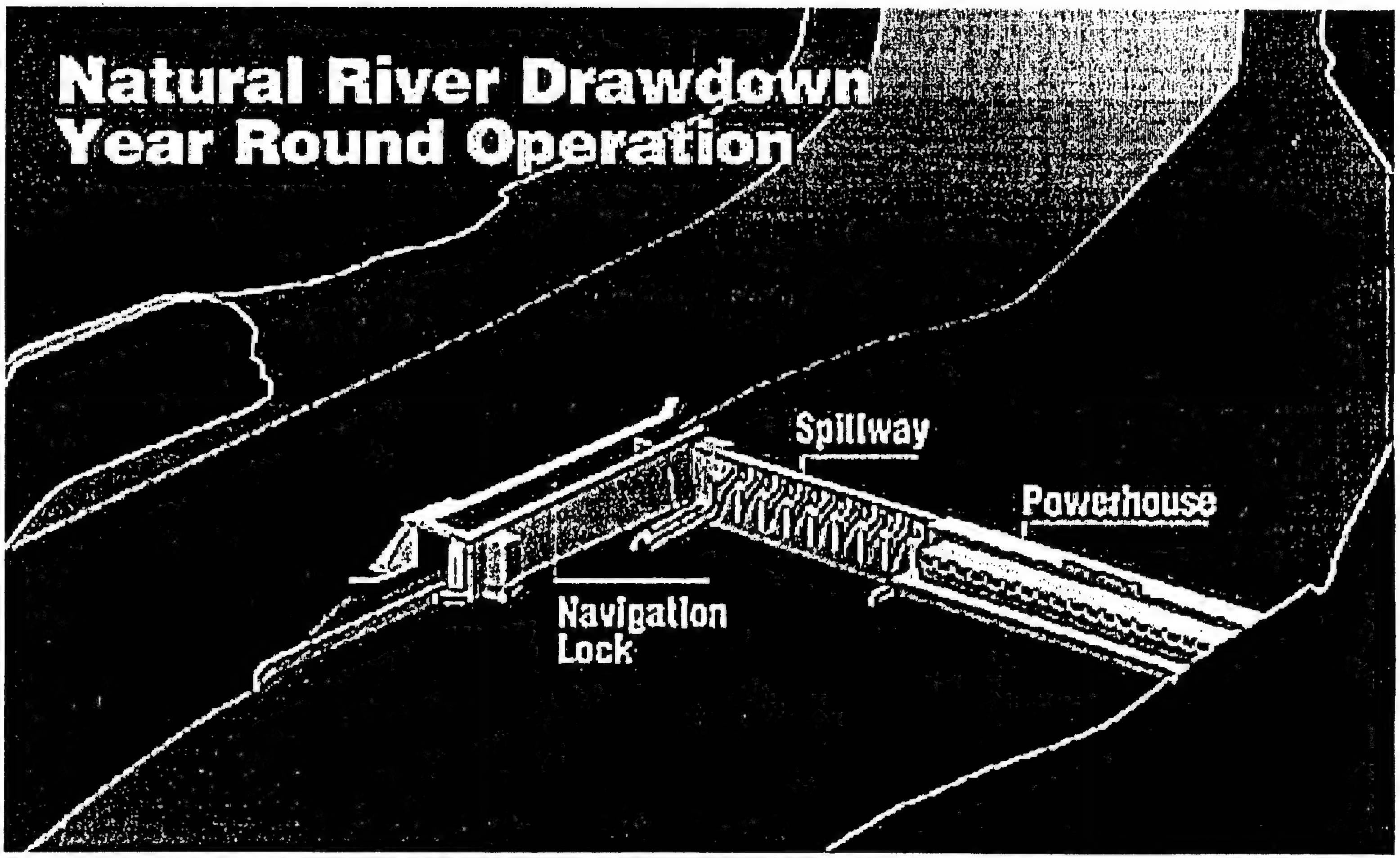

Figure 3-3. Conceptual View of Changes at a Dam with the Natural River Drawdown Alternative

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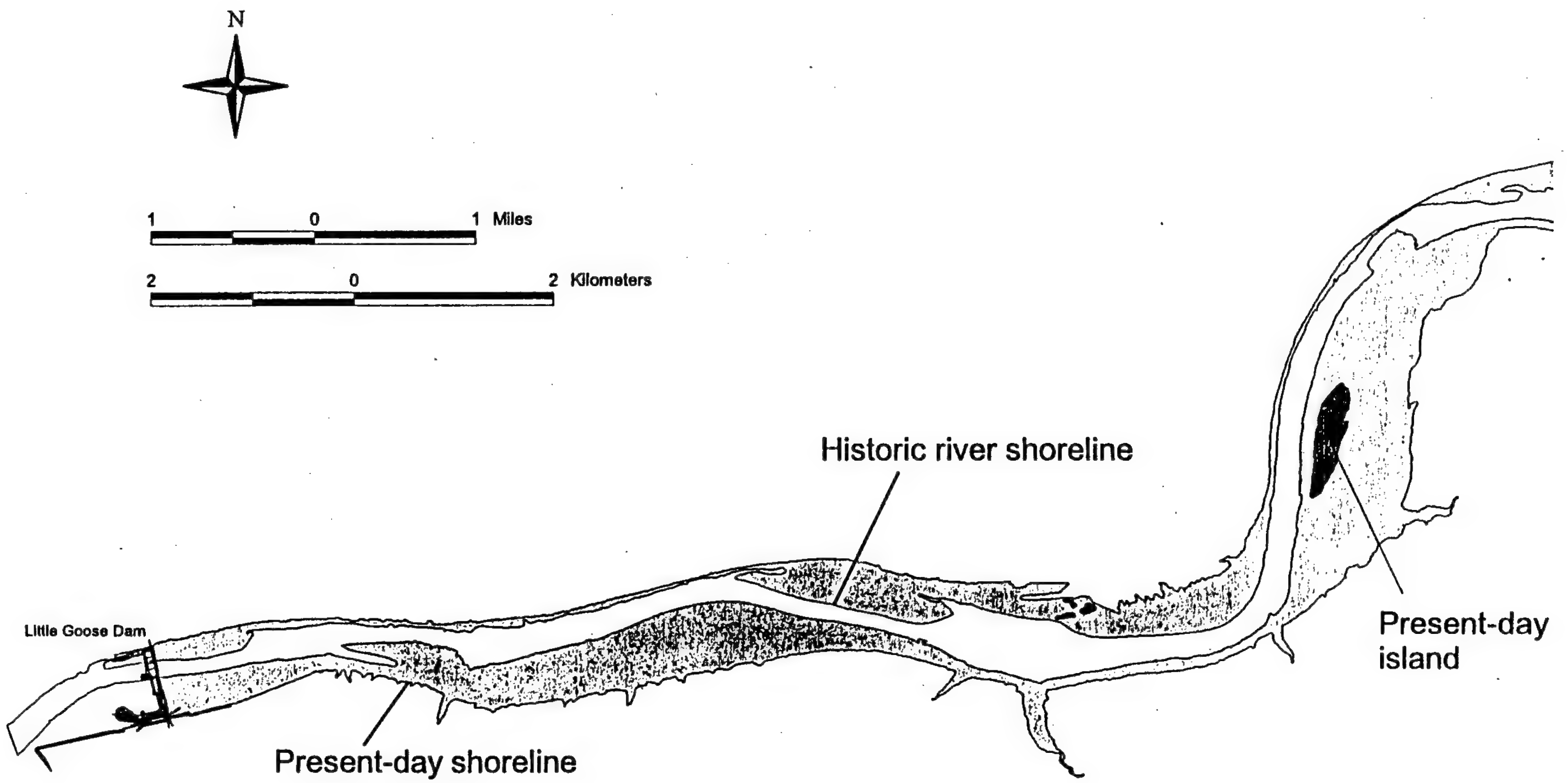

Figure 3-4. Conceptualization of Reservoir Drawdown Showing Areas That Would Be Dewatered as the Shoreline Returns to the Historic River Channel

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4. Pre-Dam Resources

4.1 Anadromous Fish (Pre-Dam)

The Independent Scientific Group (1996) described the ecosystem that sustained the salmon populations of the Columbia River Basin as a "normative" system where a continuum of high quality habitat was available for fish from spawning sites to the ocean. The Snake River Basin originally provided such habitat from its headwaters to the Columbia River. Limited detailed information is available regarding habitat conditions in the lower Snake River before dam construction. An examination of 1934-1935 survey data by Hanrahan et al. (1998) from the Lower Granite Reservoir area showed that rapids, pools, and riffles were present in that reach of river. Thirteen rapids ranging for 47,846 to 464,520 m^2 (515,000 to 5,000,000 square feet) in area, 46 pools ranging from 28 to 222,969 m^2 (300 to 2,400,000 square feet) in area, and 23 riffles ranging from 8,733 to 455,299 m^2 (94,000 to 4,900,000 square feet) in area were identified from the 1934-1935 survey. The Corps (Technical Appendix H) determined that the pre-dam channel was a "morphologically diverse, coarse-bedded, stable river possessing a meandering thalweg and classic pool-riffle longitudinal bedform profile (Corps, 1999). The Independent Scientific Group described the Snake River as a classic, gravel-bed river dominated by gravel and cobble. The river channel included bars, islands, runs, and pools with backwaters, side channels, and sloughs. These areas produced large numbers of aquatic insects that are food items for juvenile salmonids. The Independent Scientific Group also summarized the characteristics of high quality riverine habitat for salmonids. Characteristics included clean, stable substrates for spawning and low velocity areas for juvenile rearing such as backwaters and side channels. Such areas are thought to have been present in the lower Snake River.

Before construction of the four lower Snake River dams and the Hells Canyon dam complex, the Snake River System was one of the major producers of anadromous fish in the Columbia River Basin. Anadromous fish used the mainstem Snake River and its tributaries for spawning, rearing, and as a migration route. Anadromous salmonids that were present included spring, summer, and fall races of chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), sockeye salmon (*Oncorhynchus nerka*), and steelhead (*Oncorhynchus mykiss*). Figure 4-1 shows the original distribution of anadromous salmonids in the Snake River Basin. Other anadromous fish that inhabited the Snake River System included white sturgeon (*Acipenser transmontanus*) and Pacific lamprey (*Lampetra tridentata*). It is estimated that the Idaho portion of the Snake River Basin alone once produced 39 percent of the total spring chinook salmon, 45 percent of the total summer chinook salmon, 5 percent of the total fall chinook salmon, and 55 percent of the total summer steelhead in the entire Columbia River Basin (Idaho Department of Fish and Game [IDFG], 1992).

4.1.1 Chinook Salmon

Historically, three runs of chinook salmon, spring, summer, and fall, inhabited the Snake River System. The runs of chinook salmon were separated based on their times of entry into the Columbia River, spawning time, and geographic reaches of river used for spawning. Snake River spring chinook entered the Columbia River from March through May and spawned in August and early September. Summer chinook passed through the lower Columbia River and Snake rivers during June and July and spawned in September. Fall chinook generally entered the Columbia and Snake rivers from August through October and spawned in October and November. The extended time of entry into freshwater and upstream migration of these runs resulted in some overlap between the end of one run and the start of the following run.

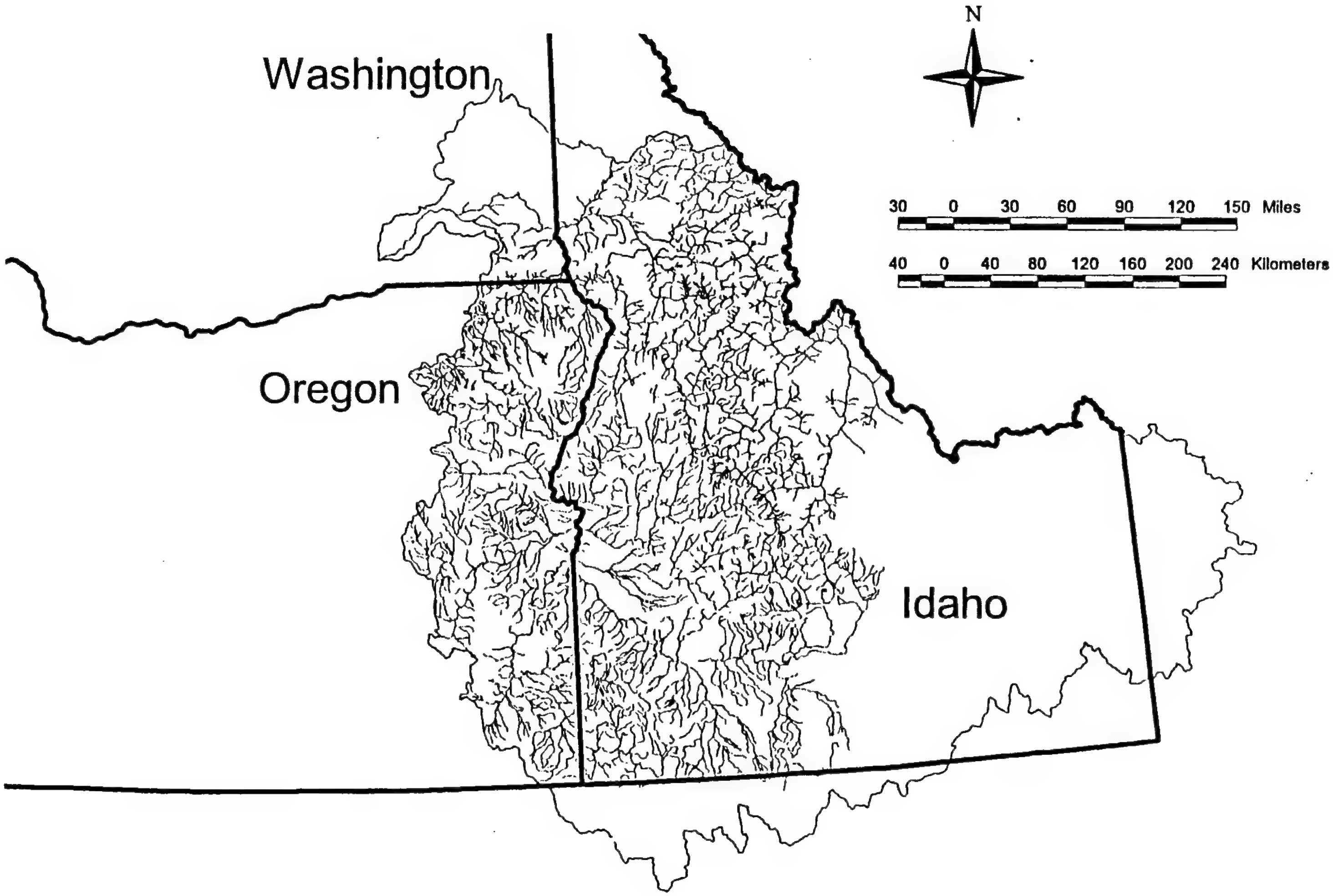

Figure 4-1. Original Distribution of Anadromous Salmonids in the Snake River Basin

Note: Distribution information was obtained from databases maintained by Streamnet (Pacific States Marine Fisheries Management Commission, Portland, Oregon).

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The date of passage at Bonneville Dam has been used to separate the runs of chinook salmon. The officially designated passage dates at Bonneville Dam for the three runs of chinook salmon are as follows: spring chinook from the beginning of the annual counting period on March 15 to May 31, summer chinook from June 1 to July 31, and fall chinook from August 1 to the end of the counting period on November 15.

4.1.1.1 Spring and Summer Chinook Salmon

Historically, spring and summer chinook salmon spawned in virtually all accessible and suitable habitat in the Snake River upstream from its confluence with the Columbia River (Fulton, 1968). Evermann (1894) reported spring-run salmon spawning as far upstream as Rock Creek, a tributary of the Snake River just downstream from Auger Falls and more than 1,442 km (896 miles) from the sea.

The Snake River was probably the major producer of spring and summer chinook salmon in the Columbia River Basin, producing about 39 percent of the spring chinook and 45 percent of the total summer chinook salmon at one time (Mallett, 1974). The estimated total production of the Snake River probably in exceeded of 1.5 million spring and summer chinook salmon for some years during the late 1800s (Matthews and Waples, 1991). The Salmon River alone was estimated to have produced about 44 percent of the spring and summer run chinook entering all tributaries of the Columbia River from 1957 to 1960 (Fulton, 1968). Adult escapement to the Snake River averaged about 37,100 spring chinook and 22,300 summer chinook from 1962 to 1974. Natural escapement of spring and summer chinook from 1955 to 1960 was estimated to have been almost 100,000 fish (IDFG et al., 1990).

Irrigation and hydroelectric power dams that were built on many upper Snake River tributaries eliminated spring and summer chinook salmon runs from those streams. Irrigation withdrawals, timber harvest and transportation practices, and gold dredging also contributed to the loss of these runs. Barber Dam on the Boise River (1906), Black Canyon Dam on the Payette River (1923), Swan Falls Dam on the mainstem Snake River (1923), Thief Valley Dam on the Powder River (1931), Unity Dam on the Burnt River (1940), Owyhee Dam on the Owyhee River (1933), and Lewiston Dam on the Clearwater River (1927) were among the larger dams in the Snake River System that eliminated native runs of spring and summer chinook salmon. Construction of the Hells Canyon complex of dams during the late 1950s blocked off all of the upper Snake River to anadromous fish access. Figure 4-2 shows the area of the Snake River Basin formerly used by anadromous salmonids that is no longer accessible.

In general, spring and summer chinook salmon spawned and reared in smaller, higher elevation tributaries of the Snake River, while fall chinook spawned in the mainstem Snake and larger lower elevation reaches of tributaries. Spring chinook salmon spawned in August and early September, while summer chinook spawned in September.

Based on the PATH retrospective conclusions, the collapse of spring/summer chinook salmon populations in the 1970s is not correlated with reduced smolt-per-spawner ratios, although habitat quality is an important factor in salmon demographics (PATH, 1996). While the annual returns of spring/summer chinook salmon declined severely in the 1970s, there was not a similar decline in habitat productivity as measured by smolts per spawner. As stated in the Corps' Technical Appendix A, Anadromous Fish, (1999), if habitat were a primary factor determining chinook salmon population declines in the Snake River, then the trend in returns should differ among tributaries with differing habitat conditions. However, the recent downward trend in returns is generally similar among stocks originating in areas with markedly different habitat conditions (PATH, 1996).

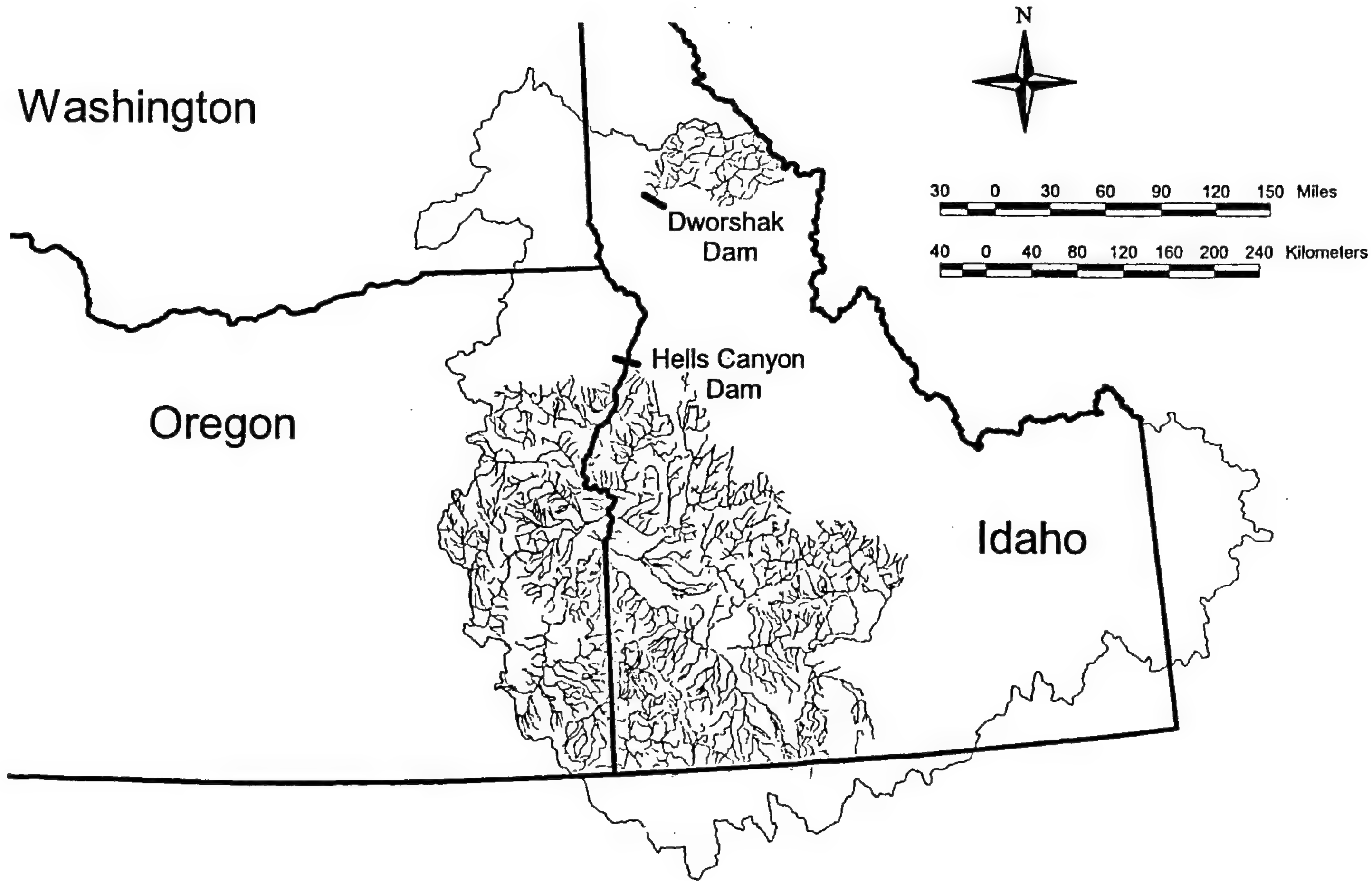

Figure 4-2. Rivers and Streams in the Snake River Basin Formerly Used by Anadromous Salmonids that are No Longer Accessible

Note: These waterways are no longer accessible due to the construction of Hells Canyon Dam and Dworshak Dam on the North Fork Clearwater River.

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4.1.1.2 Fall Chinook Salmon

The Snake River was considered in some years to be the most important producer of fall chinook salmon in the Columbia River Basin (Fulton, 1968). Estimates of fall chinook escapement to spawning areas in the Snake River from 1940 to 1955 averaged 19,447 (range = 3,300 to 30,600) (Irving and Bjornn, 1981). Production rates (that is, spawners to returning adults) for Snake River fall chinook salmon prior from 1940 to 1955 ranged from 1.9:1 to 3.2:1 (Irving and Bjornn, 1981). This stock recruitment relation reflects the healthy status of the Snake River fall chinook salmon population prior to the construction of Hells Canyon complex and the four lower Snake River dams, since the fish were replacing themselves and providing surplus adult production for harvest.

There is no empirical information on the time of year Snake River fall chinook salmon entered the mouth of the Snake River to spawn prior to 1962. In 1962, the Corps began counting adults as they passed Ice Harbor Dam. Immigrating fall chinook salmon adults passed Ice Harbor Dam in 1962 in August (8 percent of total), September (68 percent of total), and October (24 percent of the total) (Corps, 1996).

Limited spawning occurred as far upstream as Shoshone Falls about 977 km (607 miles) from the Snake River mouth (Fulton, 1968), but the core population of the fall chinook run in the Snake River Basin reportedly spawned in the 48 km (30-mile) reach of river between Marsing, Idaho (river mile 425) and Swan Falls Dam (river mile 455) (Haas, 1965). Construction of Swan Falls Dam at river mile 456 eliminated fall chinook from the reach between Swan Falls and Shoshone Falls. During periods of high fall chinook salmon escapement it is logical to assume that fall chinook salmon spawned throughout the mainstem Snake River, and in tributaries such as the Imnaha, Salmon, Grande Ronde, and Clearwater rivers (that is, the margins of the historic range). Limited redd count data for the main stem Snake River were summarized by Irving and Bjornn (1981), but there is no empirical evidence of fall chinook salmon spawning for the four tributaries listed above. Snake River fall chinook salmon spawned primarily in November (Haas, 1965), but the published literature is cryptic with respect to when spawning began and ended.

Chinook salmon fry (minimum fork length = 30 mm or 1.2 inches) were trapped at river mile 82 in March and April and in diminishing numbers in May (Mains and Smith, 1956). Mains and Smith did not identify the race of these fry, but the period over which they were captured is consistent with estimated dates for fall chinook salmon fry emergence near Marsing, Idaho (Connor et al., 1997). Bell (1957) trapped parr at river mile 213 ranging in length from 51 to 85 mm (2.0 to 3.4 inch) during May prior to peak spring runoff. Chinook salmon fingerlings (fork length range = 93 to 103 mm or 3.7 to 4.1 inches) were trapped at river mile 82 in May and June, and in small numbers in July (Mains and Smith, 1956). These fingerlings were captured near the peak, or during the descending limb of spring runoff at water temperatures ranging from 10.0 to 15.7°C (50 to 60°F). The fingerlings were probably subyearling fall chinook salmon smolts that were beginning to migrate seaward.

4.1.2 Sockeye Salmon

Snake River sockeye originally occurred in the Payette, Salmon, and Wallowa river systems. Sockeye salmon were found in five lakes in the Stanley Basin of the Salmon River System: Redfish, Pettit, Stanley, Yellowbelly, and Alturas. Sockeye salmon were also present in Big Payette Lake on the North Fork Payette River and Wallowa Lake at the headwaters of the Wallowa River.

Historically, the Snake River sockeye salmon run was estimated to have been about 150,000 fish (Northwest Power Planning Council [NPPC], 1986). The Payette River System supported the largest spawning population of sockeye salmon with 75,000 reportedly caught by a single operation in 1 year of fishing on Big Payette Lake. Returns to Wallowa River System were estimated to have ranged between 24,000 and 30,000 in the early 1880s. During the 1950s and 1960s, more than 4,000 adult sockeye returned to Redfish Lake annually. (NMFS, 1995a).

Sockeye salmon populations were drastically affected by dams which were either constructed without fishways or with inadequate fish passage facilities. Sunbeam Dam on the Salmon River blocked anadromous fish migration from 1910 to 1934. Sockeye salmon runs in the Payette and Wallowa river systems were permanently eliminated by dams which were constructed in 1924 and 1929, respectively. Redfish Lake now supports the only remaining population of sockeye salmon in the Snake River Basin. Escapement of sockeye salmon to Redfish Lake has ranged from 4,400 in 1955 to 11 in 1961 and 335 in 1964 (Waples et al., 1991).

As found in The Corps' Technical Appendix A (1999), estimates of smolt-to-adult return rates (SAR) indicate that survival has dramatically declined over the last 30 years (Marmorek et al. 1998; Marmorek and Peters, 1998). Mortality in the smolt-to-adult life stage plays a major role in the observed, parallel decline in adult returns.

As stated in the Corps' Technical Appendix A (1999), the number of hydroelectric facilities on the mainstem Snake River doubled from three to six from 1960 to 1969. SARs for 1955 through 1964 averaged 0.8 percent (Corps' Technical Appendix A [1999] citing Bjornn et al., 1968). From 1991 through 1996, average SAR declined by over 90 percent to 0.07 percent (Corps' Technical Appendix A [1999] citing C. Petrosky, Fishery Biologist, IDFG, pers. comm.). These SARs represent the survival rates of wild residual smolts from Redfish Lake which have returned as adults. As with other Snake River salmonids, the decline of Snake River sockeye salmon corresponds in time with other trends besides development of the hydrosystem (NMFS, 1999). These include the addition of unscreened diversion in tributaries connecting spawning areas with the mainstem and construction of dams that blocked fish passage.

4.1.3 Coho Salmon

Coho salmon were originally distributed in the Clearwater and Grande Ronde river tributaries, including the Wallowa, Lostine, and Wenaha rivers (Fulton, 1970). Snake River coho were among the farthest inland migrating stocks of coho salmon in the Columbia River System, traveling as far as 640 to 800 km (400 to 500 miles) to reach their spawning areas (Technical Advisory Committee [TAC], 1997). As recently as 1968, adult coho salmon counts at Ice Harbor Dam were as high as 6,000 fish. These fish were migrating to the Grande Ronde River System.

4.1.4 Steelhead

Historically, steelhead were present throughout much of the Snake River Basin that was accessible to anadromous fish. Snake River steelhead spawn at a higher elevation (up to 2,000 m or 6,500 feet) and migrate farther from the ocean (up to 1,500 km or 900 miles) than nearly any other steelhead in the world (Busby et al., 1996). Snake River steelhead are classified as summer run fish which enter the Columbia River as adults between June and October, overwinter in the mainstem Snake River or tributaries, and spawn the following spring.

Two groups of steelhead, commonly referred to as "A-run" and "B-run," occur within the Snake River Basin. The runs are differentiated based on time of upstream migration past Bonneville Dam, duration of ocean residence, and size of adults. Adult A-run steelhead are defined as those steelhead that enter fresh water and pass Bonneville Dam from June to August 25. Adult B-run steelhead are those that pass Bonneville Dam between August 25 and October 31 (TAC, 1997). However, sampling at Bonneville Dam has shown that large numbers of smaller A-run-size fish pass this site after August 25. Generally, about one half of the A-run steelhead live in the ocean for 1 year and return as "one ocean" fish, while most B-run steelhead return as "two ocean" adults. The later return from the ocean to freshwater by B-run steelhead is thought to result in a larger average size of these fish than A-run steelhead of the same ocean age.

A-run steelhead are present throughout the Columbia and the Snake River basins. In the Snake River System, A-run steelhead originally were distributed in lower elevation streams such as the Tucannon, Grande Ronde, and Imnaha rivers, lower and smaller tributaries of the Clearwater and Salmon rivers, Snake River tributaries upstream from the mid-Snake River dams, and spring-fed rivers including the Lemhi and Pahsimeroi rivers. These fish spawned in April. The B-run steelhead originated only in the Clearwater and Salmon River basins and spawned in higher elevation tributaries including the North and South Forks of the Clearwater River, Lochsa and Selway rivers, South and Middle Forks of the Salmon River, and upper Salmon River. The B-run steelhead spawned from late April through May (Bjornn and Peery, 1992).

The following is excerpted from NMFS (1999):

> *Unlike Pacific salmon, steelhead are capable of spawning multiple times before death. However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Nickelson et al. 1992). Prior to construction of most lower Columbia River and lower Snake River dams, the proportion of repeat-spawning summer steelhead in the Snake and Columbia rivers was less than 5 percent (3.4 percent [Long and Griffin 1937]; 1.6 percent [Whitt 1954]). The current proportion is unknown, but is assumed near zero.*

The Snake River System originally supported large numbers of steelhead, and it is estimated that 63.1 percent of the Columbia River Basin steelhead entered the Snake River from 1962 through 1974 (WDFW et al., 1990a). One estimate placed the number of steelhead produced in the Snake River System at 114,000 fish based on the maximum counts of fish at McNary Dam from 1954 to 1967 and the maximum percentage of the McNary Dam count passing over Ice Harbor Dam (NMFS and USFWS, 1972).

4.1.5 Pacific Lamprey

Pacific lamprey is a native anadromous fish species that coexisted with anadromous salmonids throughout the reach of the Snake River Basin that was accessible to anadromous salmonids. Historically, the geographic distribution of Pacific lamprey coincided with that of salmon. Indian tribes harvested lamprey at several locations in the Snake River Basin.

Very little run size information is available for lamprey. The Corps began counting lamprey at the adult fish ladders at Bonneville Dam in 1938, but discontinued them after 1969. Run sizes were highly variable, with annual variability in the timing of the runs and run-peaks as well as in the total numbers. Recent observations indicate that runs have declined substantially since completion of the mainstem dams in the Columbia and Snake rivers. Lamprey returns averaged 108,500 from 1938 to 1969. In 1993, a total index count of 22,366 was estimated.

The Pacific lamprey maintains a place of cultural significance in the Columbia and Snake River basins. Indians of the Pacific Coast and the interior Columbia Basin have harvested these fish for subsistence, ceremonial, and medicinal purposes for many generations. Lamprey are an integral part of Columbia and Snake River Indian tribal culture, as well as of other Indian tribal culture along the Pacific Coast (Anglin et al., 1979; Mattson, 1949; Pletcher, 1963).

4.1.6 American Shad

American shad (*Alosa sapidissima*) native to the Atlantic Coast of North America, was introduced into the Sacramento River in California in 1871, but soon spread to other waters along the Pacific Coast, including the Columbia River (1876-1877). Later (1885-1886), American shad were planted into the Columbia, Willamette, and Snake rivers, as well (Craig and Hacker, 1940). However, it is generally believed that the original introduction in the Sacramento River was responsible for the distribution of the American shad along the Pacific Coast.

In the Columbia River drainage, American shad were only moderately successful until the construction of hydroelectric dams, beginning with the completion of Bonneville Dam in 1938. Counts of American shad ranged from 2,800 to 94,500 between 1938 and 1960, with varying numbers from year to year.

American shad populations grew rapidly after the completion of The Dalles Dam in 1957, and Celilo Falls, a barrier to upstream migration of shad, was inundated. Counts of American shad at Bonneville and The Dalles dams increased thirtyfold and more after 1961. The species now extends to Wanapum Dam at Columbia river mile 416 and Lower Granite Reservoir at Columbia-Snake river mile 431. The extent of its range in the Snake River upstream from Lower Granite Reservoir is unknown.

4.2 Resident Fish (Pre-Dam)

Information on resident fish historically present in the lower Snake River is very limited. Most available information on fish refers to the abundant anadromous runs occurring throughout a large portion of the Snake River Basin, but there is little mention of resident fish. However, northern pikeminnow (*Ptychocheilus oregonenis*) and suckers (*Catostomus* sp.) did comprise a significant portion of the native culture's fish diet in certain areas.

4.2.1 White Sturgeon

Historically, white sturgeon were well dispersed throughout the Columbia River Basin from the estuary at the mouth of the river, up the Snake River to southern Idaho, and well into the Kootenai drainage of Canada and Montana. Before development of the hydroelectric facilities, sturgeon had free access to feed in the rich marine and estuarine environment of the river mouth and adjacent coastal areas and returned to the river and its major tributaries for early rearing.

Although used by Indians for thousands of years, sturgeon were still extremely abundant in the Columbia River when the first non-Indian commercial salmon gillnet fisheries began in the 1860s. At that time and for several years thereafter, tremendous numbers of sturgeon were killed by the fishermen, because the fish had no known commercial value and frequently destroyed the fishermen's nets. The non-Indian history of the Columbia River sturgeon fishery is similar to the fisheries of the East Coast, the Great Lakes, and other areas in the world where sturgeon became commercially important and were then over-fished almost to the point of extinction.

The collapse of the fishery in the late 1890s resulted in the first regulations to protect the remaining sturgeon resource. In 1897, the state of Washington closed the commercial season from March to November and required that all sturgeon under 1.2 m (4 feet) long be released. Oregon enacted the same regulations in 1899 and also prohibited the use of destructive Chinese gang lines. Eventually, fish traps, fish wheels, and seines were outlawed. For the next half century, commercial sturgeon harvests on the Columbia River remained as a small incidental catch to salmon gillnet fishing. Then, in 1950, more protective regulations were enacted. Twenty years after the adoption of minimum and maximum size limits, the Columbia River sturgeon populations again began to flourish. Sturgeon landings tripled in the 1970s and continued to set record highs in the 1980s. Current harvest in the Snake River is restricted to that area from the mouth to below Lower Granite Dam. A catch and release fishery has been and is currently in effect on all sturgeon above Lower Granite Dam.

4.2.2 Introduction of Non-native Species

When European cultures progressed to the western side of the continent, settlers felt a need to have their well-known 'pond fish' available for the dinner table (Lampman, 1946). Consequently, many non-native species were introduced into the Columbia River Basin by the turn of the twentieth century. For example, Lampman (1946) reported that carp (*Cyprinus carpio*) were well established in the Columbia River by the late 1800s and in the Snake River by 1894. Largemouth bass (*Micropterus salmoides*) were caught in the Columbia River in 1898. Several other species of sunfish, including black crappie (*Pomoxis nigromaculatus*), white crappie (*P. annularis*), bluegill (*Lepomis macrochirus*), and warmouth (*L. gulosus*), as well as yellow perch (*Perca flavescens*), also were present in the Columbia River by 1905. Channel catfish (*Ictalurus punctatus*) were first officially documented at Bonneville Dam on the Columbia River in 1945, but were suspected to be present as early as the 1920s or 1930s. Smallmouth bass were introduced to the upper Snake River in the late 1800s (Munther, 1970); they had established themselves in the lower river by the 1930s or 1940s (Keating, 1970).

4.3 Terrestrial Resources (Pre-Dam)

The study area is within the steppe and shrub-steppe province of the Columbia Basin and includes two major vegetation zones: *Agropyron spicatum-Poa sandbergii* (bluebunch wheatgrass-Sandberg's bluegrass) and *Artemesia tridentata-Agropyron spicatum* (big sagebrush-bluebunch wheatgrass) (Franklin and Dyrness, 1973). For more information on the natural plant communities that can be found in the study area refer to Franklin and Dyrness (1973) and Daubenmire (1970). Asherin and Claar (1976) include more specific information for the study area, including species found in the study area, frequency and coverage of specific species and groups, and other distribution and abundance information. Two other studies which identified specific plant species in the study area include Robberecht (1998) and Phillips (1993). Lewke (1975), Clegg (1973), and Buss and Wing (1966) include descriptions of the plant communities at the Lower Granite reservoir site before impoundment.

Precipitation is about 229 mm (9 inches) annually at the downstream end of the study area and increases to about 381 mm (15 inches) at the upstream end. This resulted in a higher occurrence of riparian vegetation in the side draws and shallow pockets across the canyon slopes in the upper half of the study area. Also, north-facing slopes retain more moisture than others and often have more diverse vegetation and more extensive woody vegetation.

Rich alluvial soils associated with the Snake River floodplain allowed the development of high quality riparian vegetation along the river. Over 50 islands were present along the river, with sand and gravel bars common. The floodplain also contained steppe and shrub-steppe vegetation and other habitats. However, before construction of any impoundments, this floodplain had been affected by the construction of railroads, grazing, and agricultural activities. Much of the floodplain was in cropland and orchards, and the riparian habitat consisted of relatively narrow bands of vegetation along the river, which widened at tributary mouths and a few other locations.

Land use before the dams included livestock grazing and hay/wheat farming along the lower portions of the river. Moving upstream, livestock grazing became the primary land use. Almost all of the land was in private ownership, and hunting in this region was fairly light, compared with some surrounding areas.

Following is a discussion of general habitat types within the study area, and then 11 groups of terrestrial wildlife species within the study area are discussed. Complete lists of wildlife species confirmed or suspected to be present within the study area are presented in Annex A.

4.3.1 Riparian Habitat

Riparian habitat is defined as the area adjacent to flowing water that contains elements of both aquatic and terrestrial ecosystems which mutually benefit each other (WDFW, 1995). These areas generally occur as relatively narrow linear units along aquatic habitats. The riparian zone has distinctive vegetation and forms an ecotone between aquatic and upland areas. That zone is typically characterized by high species diversity, densities, and productivity. Some riparian areas are also wetlands, such as palustrine scrub-shrub wetlands. Riparian areas also include areas with woody vegetation that are too dry to be classified as wetlands, sand and gravel bars, wet meadows, flood scoured areas, and other stream-related habitats and vegetation.

Riparian areas are estimated to provide less than 1 percent of the land base in the Pacific Northwest, yet they support the greatest diversity and abundance of wildlife in the arid portions of the region (USFWS, 1990). WDFW (1995) states that about 90 percent of Washington's land-based vertebrate species use riparian habitat for essential life activities. They further point out that the high wildlife value of these areas is derived from the structural complexity of vegetation, connectivity with other ecosystems, high edge-to-area ratio, abundant food and water, and a moist and mild microclimate. Moderating microclimates can be especially important during hot, dry summers and severe winters. Since riparian areas provide food, cover, and water in close proximity, they are particularly suitable for breeding by many species. Because they provide corridors of continuous habitat, they are important travel corridors for terrestrial wildlife during seasonal migration, dispersal of young, or daily movements. Furthermore, these corridors help connect otherwise isolated habitat parcels and protect against genetic isolation and extirpations of subpopulations. Aside from corridors for migration and dispersal, they also help in the diffusion of species (the spread of species into new areas, such as the brown-headed cowbird moving into new areas in the past several decades) (Malanson, 1993). Although riparian areas make up a small portion of the landscape, they are an important resource because they are very productive, diverse, and provide critical components to both aquatic and upland ecosystems.

Riparian areas are also vital to the health of the associated aquatic system. Some of the important functions they perform include the following: 1) Filtering sediments from upland water sources and causing many of the sediments in floodwaters to drop out by dissipating the water's energy, 2) Intercepting, storing, and biodegrading incoming pollutants, 3) Stabilizing streambanks, 4) Storing

floodwaters and other waters entering these areas and releasing such waters more gradually. 5) Cooling water in summer and warming it in winter, 6) Providing large woody debris to the aquatic system which dissipates energy, retains detritus and salmonid carcasses, and maintains structural diversity, 7) Providing plant materials, insects, and other materials that are the basis for the aquatic food web, 8) Often providing off-channel habitats such as side channels, sloughs, and seasonal wetlands. While riparian areas are often thought of as important for terrestrial wildlife, they are also vital to fish and other components of the aquatic system.

Before any impoundments were constructed, there was still nearly 1,336 ha (3,300 acres) of woody riparian habitat present (USFWS, 1991). This habitat was comprised of riparian forest, mesic shrubland, and palustrine scrub-shrub. Riparian forest was characterized by black cottonwood (*Populus trichocarpa*), white alder (*Alnus rhombifolia*), black locust (*Robinia psuedoacacia*), and netleaf hackberry (*Celtis reticulata*). Clegg (1973) found netleaf hackberry at nearly all of the 58 sample sites at the Lower Granite Reservoir site. Mesic shrubland is often found in side draws and areas with at least seasonal springs and seeps. In the study area, these areas are characterized with netleaf hackberry, Douglas hawthorn (*Crataegus douglasii*), smooth sumac (*Rhus glabra*), rose (*Rosa* sp.), chokecherry (*Prunus virginiana*), and blackberry (*Rubus discolor*). Palustrine scrub-shrub habitat is actually wetlands dominated by shrubs and would have been found right along the river shoreline and on islands. Characteristic shrubs included coyote willow (*Salix exigua*), other willows (*Salix* spp.), and young black cottonwood and white alder.

USFWS (1991) found that, in addition to woody cover, riparian habitat also included forbland, whose name was later changed to perennial forb and grasses (AFG) and emergent wetlands. Only 4 ha (10 acres) of emergent wetlands were estimated to be present pre-impoundment. This habitat is characterized by cattail (*Typha latifolia*), softstem bulrush (*Scirpus validus*), and sedges (*Carex* sp.). AFG habitat is often subirrigated and is usually comprised of a relatively lush growth of annual and perennial forbs and grasses. Over 769 ha (1,900 acres) of AFG were present pre-impoundment, with characteristic vegetation including teasel (*Dipsacus sylvestris*), prickly lettuce (*Lactuca serriloa*), thistles (*Cirsium* spp.), curly dock (*Rumex crispus*), cheatgrass (*Bromus tectorum*), bluebunch wheatgrass, and intermediate wheatgrass (*Agropyron intermedium*) (USFWS, 1991).

4.3.2 Upland Habitat

Before reservoir construction, there was nearly 3,116 ha (7,700 acres) of shrub-steppe within the study area (Table 4-1). Much of it had been degraded by overgrazing with livestock. Some shrub-steppe had also been removed to facilitate farming and orchards. The majority of Washington's shrub-steppe habitat has been lost in the past century, with most of the remaining habitat fragmented and occurring in small parcels (Dobler et al., 1996). These shrub-steppe communities still support a wide diversity of wildlife, although they have lowered suitability for many native species. Dobler et al. (1996) believed that many of the species found using shrub-steppe in eastern Washington (for example, the two most common species: western meadowlark and horned lark) were likely there, or there in high numbers, because of the interspersion of agricultural lands, waterways, the U.S. Department of Agriculture's Conservation Reserve Program lands, etc. They also found that bird species diversity increased with diversity of the shrub-steppe community. There is no documentation of the four bird species listed as shrub-steppe obligates (sage grouse, sage sparrow, sage thrasher, and Brewer's sparrow) within the study area.

Table 4-1. Acreages of Habitat Types at the Four Lower Snake River Facilities Based on Cover Type Information1/

Habitat types	Lower Two Facilities2/ Pre-construction	Lower Two Facilities2/ 1997	Upper Two Facilities3/ Pre-construction	Upper Two Facilities3/ 1997	Totals Pre-construction	Totals 1997
Riparian forest	202.2	304.0	508.6	164.0	710.8	468.0
Palustrine scrub-shrub	804.2	301.4	932.4	290.9	1,736.6	592.3
Mesic shrub	42.1	199.8	795.2	582.0	837.3	781.8
Perennial forb and grass (AFG)	686.4	369.5	1,229.3	399.9	1,915.7	769.4
Palustrine emergent	4.0	250.0	5.9	103.2	9.9	353.2
Shrub-steppe	5,019.2	4,051.1	2,655.1	1,412.5	7,674.3	6,453.6
Grassland (steppe)	6,078.9	3,481.9	7,179.8	6,293.5	13,288.7	9,775.4
Agricultural land	1,206.3	214.2	3,437.0	105.4	4,643.3	319.6

1/ Based on USFWS (1991) and cover typing completed by USFWS and Corps in 1997.

2/ Includes Ice Harbor and Lower Monumental facilities.

3/ Includes Little Goose and Lower Granite facilities.

Before reservoir construction, the majority of the grassland (steppe) vegetation in and near the study area had either been converted to agricultural land or was being overgrazed. Pockets of native grassland vegetation (bluebunch wheatgrass-Sandberg's bluegrass community) remained on very steep slopes and other areas inaccessible to grazing; otherwise, much of the native vegetation had been replaced with cheatgrass. Grassland represented the largest habitat type present within the study area, with nearly 5,383 ha (13,300 acres) present before inundation.

Agricultural land before inundation by the four reservoirs was found mainly on the deeper soils of the Snake River floodplain. It included cropland, pasture, and orchards. There was over 1,862 ha (4,600 acres) of agricultural land in the study area before inundation.

4.3.3 Habitat Evaluation Procedures

As described earlier, the Compensation Plan was developed to mitigate for fish and wildlife losses from constructing the four lower Snake River reservoirs. Originally, the terrestrial portion of this involved determining wildlife losses based on population estimates of principal game species (Corps, 1975). Efforts to determine compensation progress were also measured by animal numbers (Mudd et al., 1980); however, concerns arose over use of this method for determining compensation (USFWS, 1991). Subsequently, it was determined that a habitat-based method should be used to establish compensation goals and measure compensation progress. This was formalized in a Letter of Agreement (LOA) signed by the Corps, USFWS, and the Washington Department of Wildlife (now

WDFW) in 1989. Purposes and criteria included in the LOA can be found in USFWS (1991). These agencies agreed to use a modified habitat evaluation procedures (HEP) method.

HEP is a species-based habitat analysis procedure, that normally involves representatives from several agencies or other groups. USFWS, the Corps, and WDFW were all actively involved in this procedure. The procedure assesses the value of the habitat for certain selected species over the life of the facility. The species evaluated are selected either to represent entire groups of species (for example, river otter may be used to represent furbearers), because of some special value they have in the area (for example, popular game birds), or to evaluate a certain habitat type. Compensation Plan evaluation species included twelve birds and mammals: downy woodpecker, yellow warbler, marsh wren, song sparrow, western meadowlark, California quail, ring-necked pheasant, chukar, mallard, Canada goose, mule deer, and river otter. Table 4-2 identifies the species group or habitat type each of the evaluation species represents.

Once species were selected, models which describe a range of habitat values for that species were obtained or written. These models generally relate certain aspects of the habitat, such as percent ground cover or height of vegetation, to the value of the habitat for that particular species. The models rank the habitats on a scale from 0.0 to 1.0, with 0.0 being of no value and 1.0 being of highest value. These scores are known as habitat suitability indices (HSI) and may change over time as the habitat changes. In most models, once the HSI scores are determined for each species, they are simply multiplied by the number of acres of habitat available to the species to derive a measure which takes into account both the habitat quality and quantity. This measure is called a habitat unit (HU). For some species, however, the models also include calculations based on different life requisites. For example, for ring-necked pheasant these include nesting cover, winter cover, and winter food. The model for pheasants dictates that for optimal pheasant habitat at least 80 percent of the area should provide nesting cover, at least 30 percent should provide winter cover, and at least 50 percent should provide winter food.

The HUs can then be altered either by changes in the number of acres of habitat available to a species or by changes in the quality of available habitat. The final output of a HEP analysis is the number of HUs available for each species used in the analysis. The results from the HEP can then be used to compare the future with and without conditions to provide an estimate of the facility-related impacts to wildlife. Further details regarding the HEP procedures, cover types, assumptions, models, and model references can be found in USFWS (1991) and USFWS (1988).

To determine habitat values for habitat present in the study area before inundation, 1958 aerial photography was used, along with HEP measurements made in habitats deemed similar to that lost. For example, some sites for measurement included habitats along tributaries just upstream from reservoir boundaries. The HUs that were projected to be lost due to inundation of the four lower Snake River reservoirs are shown in Table 4-2.

4.3.4 Game Birds

While there were generally fewer birds and other animals observed during studies that took place before the impoundments were constructed, studies were not extensive. Also, several studies were conducted after construction with more intensive and comprehensive data collected (for example, Rocklage and Ratti, 1998) or that covered a several-year period (for example, annual data collected by Corps biologists at the various facilities). Furthermore, scientific methods and standards have improved since some of those earlier studies.

Table 4-2. Habitat Evaluation Procedures (HEP) Analyses for the Lower Snake River Study Area from Preproject to 1997

Evaluation Species (cover type or species group)	Preproject (1958) Habitat Units	1987 Habitat Units[1/]	1997 Habitat Units[2/]	Compensation Balances[3/]
Downy woodpecker (Riparian forest)	710.8	48.5	301.2	- 409.6
Song sparrow (Riparian forest understory)	685.4	126.0	670.3	- 15.1
Yellow warbler (Palustrine scrub-shrub)	1,164.2	196.4	454.3	- 709.9
Marsh wren (Emergent wetland)	1.1	13.4	78.4	77.3
Song sparrow (Mesic shrubland)	830.1	554.7	1,125.4	295.5
Western meadowlark (Shrubsteppe/grassland)	7,879.1	6,092.9	9,188.7	1,309.6
River otter (Furbearer)	3,174.9	3,903.3	4,041.0	866.1
Mule deer (Big game)	8,243.7	5,468.1	8,777.8	534.1
California quail (Upland game bird)	28,029.5	4,040.2	7,043.7	- 20,985.8
Ring-necked pheasant (Upland game bird)	7,505.4	2,879.6	4,182.6	- 3,322.8
Chukar (Upland game bird)	9,919.8	6,649.1	8,754.5	1,165.3
Mallard (Waterfowl)	89.9	117.7	141.9	52.0
Canada goose (Waterfowl)	3,870.6	1,810.6	1,810.7	- 2,059.9

1/ 1987 HEP analyses included HUs present on facility lands only.
2/ 1997 HEP analyses included HUs present on both facility lands and off-facility lands.
3/ Positive numbers indicate that habitat losses have been exceeded by compensation, and negative numbers indicate the remaining losses still to be compensated.

Game birds were one of the main species of concern when deciding on mitigation plans and attempts were made to maximize or optimize habitat for these species on facility lands. Those present on the study area before inundation included ring-necked pheasant (*Phasianus colchicus*), California quail (*Callipepla californica*), gray partridge, (*Perdix perdix*), chukar (*Alectoris chukar*), mourning dove (*Zenaida macroura*), and waterfowl. Only the mourning dove and waterfowl are native species. Most of the game birds relied heavily on riparian habitats, although chukars and gray partridge used more upland areas. Chukars seemed to prefer very rocky areas, such as talus slopes, and were found to concentrate along the Snake River when other sources of water were unavailable during summer and fall (Asherin and Claar, 1976). Mourning doves use a variety of habitats throughout the study

area, but normally nest in trees and shrubs. Gray partridge use shrub-steppe and adjacent agricultural lands. Ring-necked pheasant and California quail use the various riparian habitats for several life requisites, and both would have used some of the agricultural lands.

4.3.5 Waterfowl

Eighteen waterfowl species were documented using the Lower Granite project site before the reservoir was constructed (Buss and Wing, 1966; Lewke and Buss, 1977). The most common waterfowl species, in decreasing order of abundance, were mallard (*Anas platyrhynchos*), common goldeneye (*Bucephala clangula*), and Canada goose (*Branta canadensis*). Population levels of waterfowl were fairly stable between 1943 to 1950 (about 50,000 to 100,000 birds) in the Snake and Columbia river plains (Ducks Unlimited, 1994).

An average of about 220 breeding pairs of Canada geese were found along the lower Snake River from 1947 to 1953 from its mouth to a few miles upstream of the current Lower Granite Dam (Yocom, 1961). They nested mainly on cliffs along the river and on islands. On six islands that were later inundated with Little Goose and Lower Granite reservoirs, Buss and Wing (1966) found an annual average of 20.7 Canada goose nests over 11 years. However, over 50 islands larger than 2 ha (5 acres) in size were inundated when the reservoirs were constructed (Corps, 1988).

4.3.6 Shorebirds

Shorebird habitat was extremely limited prefacility as is normal for most flowing systems, especially since backwaters, wetlands, and other good shorebird habitats were almost nonexistent along the lower Snake River (USFWS, 1991). However, sand and gravel bars were relatively common and they would have provided suitable habitat for killdeer and spotted sandpiper. The only shorebirds seen at the Lower Granite Reservoir site by Asherin and Claar (1976) before inundation were killdeer (*Charadrius vociferus*), greater yellowlegs (*Tringa melanoleuca*), spotted sandpiper (*Actitis macularia*), and least sandpiper (*Caladris minutella*). The only ones seen on the Snake River along lower Hell's Canyon were killdeer and spotted sandpiper (Rocklage and Ratti, 1998).

4.3.7 Colonial-nesting Birds

There were some colonial-nesting birds present during breeding season surveys conducted before inundation by the Lower Granite Reservoir, including California gull (*Larus californicus*), ring-billed gull (*Larus delawarensis*), bank swallow (*Riparia riparia*), and cliff swallow (*Hirundo pyrrhonoya*) (Lewke and Buss, 1977). However, Asherin and Claar (1976) found no rookeries or nesting by colony-nesting birds, and there is no mention of any in other literature.

4.3.8 Raptors

Raptor species documented in the Lower Granite Reservoir site by Lewke and Buss (1977) included Cooper's hawk (*Accipiter cooperii*), northern harrier (*Circus cyaneus*), red-tailed hawk (*Buteo jamaicensis*), rough-legged hawk (*Buteo lagopus*), American kestrel (*Falco sparverius*), and great horned owl (*Bubo virginianus*). In addition, Dumas (1950) found prairie falcons (*Falco mexicanus*) nesting on rocky cliffs in southeastern Washington, such as those along the lower Snake River. Most of the nests found along the Snake River within the study area in 1981 were on cliffs and rocky areas (Fleming, 1981). These areas were likely used by nesting raptors before inundation by the reservoirs and may also have included such species as barn owl (*Tyto alba*), golden eagle (*Aquila chrysaetos*), and osprey (*Pandion haliaetus*).

4.3.9 Other Non-game Birds

Dumas (1950) collected breeding bird data during 1948 in an area that included the lower Snake River from just upstream of Ice Harbor Dam to just upstream of Little Goose Dam and the lower reaches of the Tucannon, Touchet and Walla Walla rivers. Sixty-one species were found along the water margins, within the floodplain forests, or on rocky cliffs. Dumas (1950) found nine species prefacility in an area that was largely within the study area, but these species were not found recently (Rocklage and Ratti, 1998; S. Ackerman, Corps, personal communication). They include: western screech owl (*Otus kennicottii*), ruffed grouse (*Bonasa umbellus*), black-chinned hummingbird (*Archilochus alexandri*), Lewis' woodpecker (*Melanerpes lewis*), veery (*Catharus fuscuscens*), red-eyed vireo (*Vireo olivaceus*), solitary vireo (*Vireo solitarius*), American redstart (*Setophaga ruticilla*), and Brewer's blackbird (*Euphagus cyanocephalus*). While the ruffed grouse and American redstart were likely seen at higher elevations on one of the tributary rivers, nearly all of the other species could have been found in riparian forest habitat along the lower Snake River.

At the Lower Granite Reservoir site (prefacility), significantly more birds were found below the perspective pool level than would be expected (Lewke and Buss, 1977). Up to 63 percent of all bird sightings were in riparian habitats. About 50 percent of the 129 species observed were found to be significantly dependent upon tree/shrub riparian habitat, and 26 percent were significantly dependent upon riverbank-floodplain habitat.

Lewke (1975) found weedy and riparian habitats at the Lower Granite Reservoir site to be very important for birds in winter. Lewke and Buss (1977) found the diversity of avian species to be significantly higher in habitats associated with the Lower Granite Reservoir site (prefacility) than with the other lower Snake River Reservoirs.

Since there was a very small amount (4 ha or 10 acres) of emergent wetlands estimated along the lower Snake River before inundation by reservoirs (USFWS, 1991), there were likely few wetland-dependent species, such as yellow-headed blackbird (*Xanthocephalus xanthocephalus*), marsh wren (*Cistothorus palustris*), and sora rail (*Porzana carolina*). The red-winged blackbird (*Agelaius phoeniceus*) was found at the Lower Granite Reservoir site by Lewke and Buss (1977); however, this species will use other habitats aside from emergent wetlands.

Lewke and Buss (1977) compared bird transects from along Little Goose and Lower Monumental reservoirs and the north and south sides of the Lower Granite facility site. The Lower Granite transects had the greatest average numbers of individuals for each season. They found that in all seasons, the Lower Granite South (LGS) transects had the greatest average numbers of species in all seasons and significantly higher bird species diversity indices than all other areas. This was likely due to the better quality riparian habitat present along the LGS transect than was present in other areas. Areas along Little Goose and Lower Monumental reservoirs would have had only recent habitat developments completed. Furthermore, the LGS transects often had a northern exposure that would result in vegetation whose structure and composition was more diverse.

4.3.10 Big Game Animals

The restricted acreage of riparian vegetation, steep topography, and fluctuating water levels is a significant factor affecting populations of mammals along the lower Snake River. White-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) are the only big game animals found in the prefacility study area in any numbers (Asherin and Claar, 1976), with mule deer the most common. Mule deer historically used the islands and adjacent bottomlands as fawning and wintering

areas. Other big game animals that were likely present prefacility, though in small numbers, include elk (*Cervus elaphus*), bighorn sheep (*Ovis canadensis*), and mountain lion (*Felix concolor*).

4.3.11 Small Mammals

Species caught during studies at the Lower Granite Reservoir study area (pre-impoundment) included the following, in decreasing order of abundance: deer mouse (*Peromyscus maniculatus*), western harvest mouse (*Reithrodontomys megalotis*), vagrant shrew (*Sorex vagrans*), house mouse (*Mus musculus*), Great Basin pocket mouse (*Perognathus parvus*), montane vole (*Microtus montanus*), and long-tailed vole (*Microtus longicaudus*) (Lewke and Buss, 1977). The deer mouse was by far the most abundant species and accounted for 93 percent of the captures. The only small mammal caught in studies by Asherin and Claar (1976) at the Lower Granite Reservoir site was the deer mouse.

4.3.12 Bats

There is little information on bats in the study area before inundation. However, Asherin and Claar (1976) collected the following species along a segment of the lower Snake River which extended from Lewiston to about 32 km (20 miles) upstream of the study area boundary: Yuma myotis (*Myotis yumanensis*), western pipistrelle (*Pipistrellus hesperus*), and big brown bat (*Myotis fuscus*). Many of the bats found in the region would forage near or over water or around cliffs and rock outcrops and would roost in trees and shrubs, rock crevices, and buildings (Cassidy et al., 1997). Most, if not all, of those species found within the study area after reservoir construction, were likely present before inundation.

4.3.13 Furbearers

Five terrestrial furbearers that would have been found in the study area prefacility include badger (*Taxidea taxus*), coyote (*Canis latrans*), raccoon (*Procyon lotor*), bobcat (*Felix rufus*), and striped skunk (*Mephitis mephitis*) (Asherin and Claar, 1976). All of these would either require or at least select riparian habitat, except for badger, which would be found in shrub-steppe, steppe, and adjacent agricultural areas. Aquatic furbearers found in the study area prefacility would have included beaver (*Castor canadensis*), mink (*Mustela vison*), muskrat (*Ondatra zibethicus*), and river otter (*Lutra canadensis*). They generally occur in riparian and emergent wetland habitats.

4.3.14 Amphibians and Reptiles

Little information is available on amphibians and reptiles present within the study area before inundation by the four reservoirs. Asherin and Claar (1976) found five species at the Lower Granite Reservoir site, including bullfrog (*Rana catesbiana*), western skink (*Eumeces skiltonianus*), racer (*Coluber constrictor*), western rattlesnake (*Crotalus viridis*), and gopher snake (*Pitouphis catenfir*). Also, they suspected long-toed salamander (*Ambystoma macrodactylum*) would have been present, although they were unable to detect it. Furthermore, they found western toad (*Bufo boreas*), Pacific tree frog (*Hyla regilla*), western fence lizard (*Scleropus occidentalis*), western terrestrial garter snake (*Thamnophis elegans*), and common garter snake (*Thamnophis sirtalis*) along the segment of the Snake River from Lewiston to about 32 km (20 miles) upstream of the study area boundary. Some species, such as the painted turtle (*Chrysemys picta*), prefer slow-moving water or wetlands and were likely not present prefacility.

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5. Post-Dam Resources

5.1 Anadromous Fish (Post-Dam)

Naturally produced spring, summer, and fall chinook salmon, sockeye salmon, and steelhead continue to use the Snake River and its accessible tributaries, although their abundance has declined drastically. Appendix B identifies current distributions of anadromous salmonids. Sockeye salmon have been reduced to a remnant population that is close to extinction. Snake River coho salmon were declared extinct, but other stocks have been reintroduced to reestablish a population. Hatchery production has helped to maintain the adult returns of some anadromous salmonids, such as steelhead. Figure 5.1 shows the number of adult salmon and steelhead counted annually at Ice Harbor Dam since 1962.

The decline in Snake River anadromous salmonids has been attributed to many factors including habitat loss, hatchery practices, harvest, the hydropower system in the Columbia/Snake River system, and variations in climatic or ocean conditions. While it is likely that all of these factors have contributed to this decline, the purpose of this report is to address the dam and reservoir system in the lower Snake River and the alternatives for improving the status of anadromous fish. Other human-caused impacts to anadromous salmonids in the Federal Columbia River Power system are being addressed through many additional efforts.

NMFS noted that changes in climatic or oceanic conditions have been hypothesized as a potentially major factor affecting Snake River salmon survival (NMFS, 1999). Under these hypotheses, salmon stocks would improve without any management if ocean conditions improved. If ocean conditions declined or stayed the same, then they would mask or limit the ability of management to recover stocks. The National Research Council (NRC) notes that there is little humans can do in the short term to control or even predict large-scale changes in environmental conditions, but suggests that salmon management programs must expect these changes and take them into account (NRC, 1996). The NRC also notes that Some might be tempted to attribute all changes in salmon abundance to changes in ocean conditions and to conclude that management related to rivers is therefore unimportant. However, because all human effects on salmon are reductions in the total production that the environment allows, management interventions are *more* important when the ocean environment reduces natural production than when ocean conditions are more favorable (NRC, 1996).

Habitat for anadromous salmonids has been greatly altered by the dams and reservoirs in the lower Snake River. Dam construction for hydropower, irrigation, navigation, and other uses has disrupted the continuum of high quality habitat, leaving little riverine habitat in the lower Snake River and isolating other habitats. The major change has been the inundation of productive riverine habitat. The Independent Scientific Group has reviewed the riverine and impounded ecosystem conditions in the Snake and Columbia rivers. This group indicated that destruction of riverine habitat upstream of dams and its conversion to reservoir habitat, are major consequences of dams. In many cases, reservoirs flooded out the alluvial valleys that were most the important spawning and rearing habitats for anadromous salmonids. Another result of dam construction and operation has been the creation of artificial flow, thermal, and sediment regimes downstream from the dams.

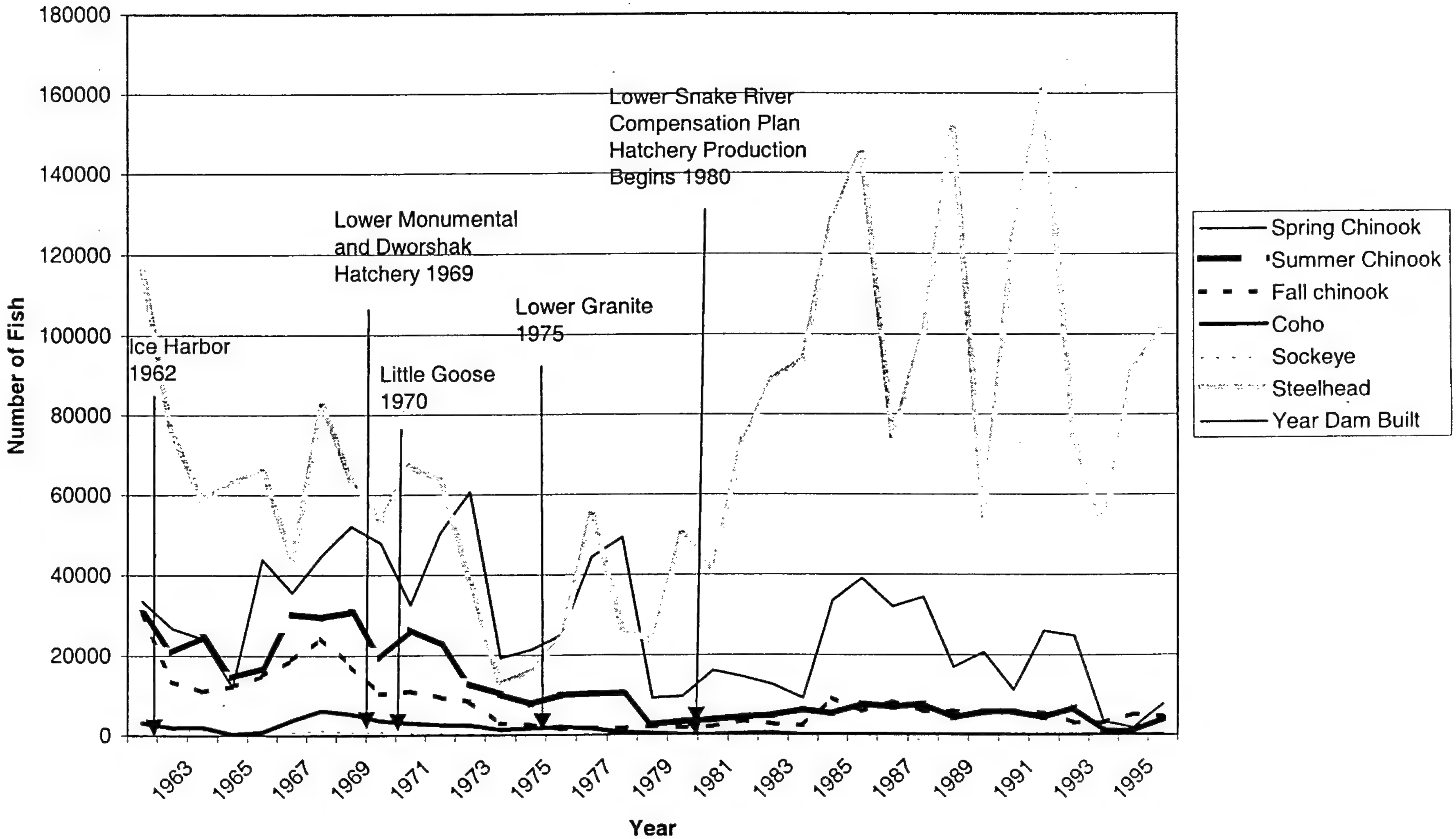

Figure 5-1. Annual Counts of Adult Anadromous Salmonids st Ice Harbor Dam, 1962 to 1995

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Conversion of riverine habitat to a reservoir has affected the quality of food available to juvenile salmonids in the Snake River system. The Independent Scientific Group has stated that impoundment and flow regulation have resulted in an ecosystem that does not appear capable of producing as much high quality food for juvenile salmonids as the former free-flowing and annually flooding river system. Riverine reaches that supported insects such as caddisflies, mayflies, and other insects that juvenile salmonids fed upon have been replaced by reservoirs inhabited by midges, aquatic worms, and zooplankton. Aquatic insects associated with riverine conditions are present only at the upper ends of the reservoirs.

Streamside vegetation provided food for juvenile salmonids during the spring when annual flooding covered shoreline areas. Flooding of riparian vegetation is important to newly emerged fall chinook salmon fry which inhabit shallow water near the shoreline. Submerged riparian vegetation was thought to be an important substrate for aquatic insects and terrestrial insects. These areas have been inundated by reservoirs whose shorelines now consist primarily of unvegetated rock riprap and eroding banks.

5.1.1 Chinook Salmon

5.1.1.1 Spring and Summer Chinook Salmon

Information from the United States versus Oregon Technical Advisory Committee (TAC) All Species Review (TAC, 1997) indicates that wild production in the Snake River Basin was responsible for returns of 50,000 to 80,000 spring chinook salmon to the Columbia River during the 1960s. Snake River spring chinook production has declined since that time to fewer than 10,000 fish in recent years. Figure 5-2 shows the number of spring and summer chinook salmon counted annually at Ice Harbor Dam since 1962. About 55 to 75 percent of these fish are hatchery produced. Wild spring chinook production in the Snake River System has declined to about 10 to 20 percent of former levels since the construction of the lower Snake River dams and continues to decline. This decline has continued even though harvest of upper Columbia and Snake River spring chinook has been nearly eliminated (TAC, 1997). Spring chinook salmon presently occur in five major tributaries of the Snake River including the Clearwater, Salmon, Grande Ronde, Tucannon, and Imnaha rivers. Smaller tributaries including Asotin, Granite and Sheep creeks are also used by spring chinook (WDFW et al., 1990a).

Snake River summer chinook salmon runs have also declined drastically in the past 30 years. From 1962 to 1985, the average count of summer chinook at the uppermost Snake River dam was about 11,800 fish. The average count dropped to about 3,200 between 1991 and 1995 and reached record lows in 1994 and 1995 (TAC, 1997). Both wild and hatchery summer chinook experienced comparable decreases in returns of adult fish during this period. Summer chinook salmon presently return primarily to the Salmon River, but also occur in the Clearwater and Imnaha rivers.

Spring and summer chinook redd counts used to indicate trends in wild fish populations have shown a drastic decline in recent decades. Index counts of redds in the Snake River Basin declined from over 13,000 in 1957 (excluding Grande Ronde River counts) to 8,542 in 1964 (including Grande Ronde River counts). Index counts reached a low of 620 redds in 1980, increased to a peak of 3,395 in 1988, and then fell to about 1,000 to 1,200 in 1989 and 1990 (Matthews and Waples, 1991).

Adult Snake River spring chinook enter the Columbia River from mid-March through May. The timing of entry into the Columbia River varies somewhat depending on the stock of fish. For example, spring chinook bound for the Salmon River System pass Bonneville Dam from mid-March

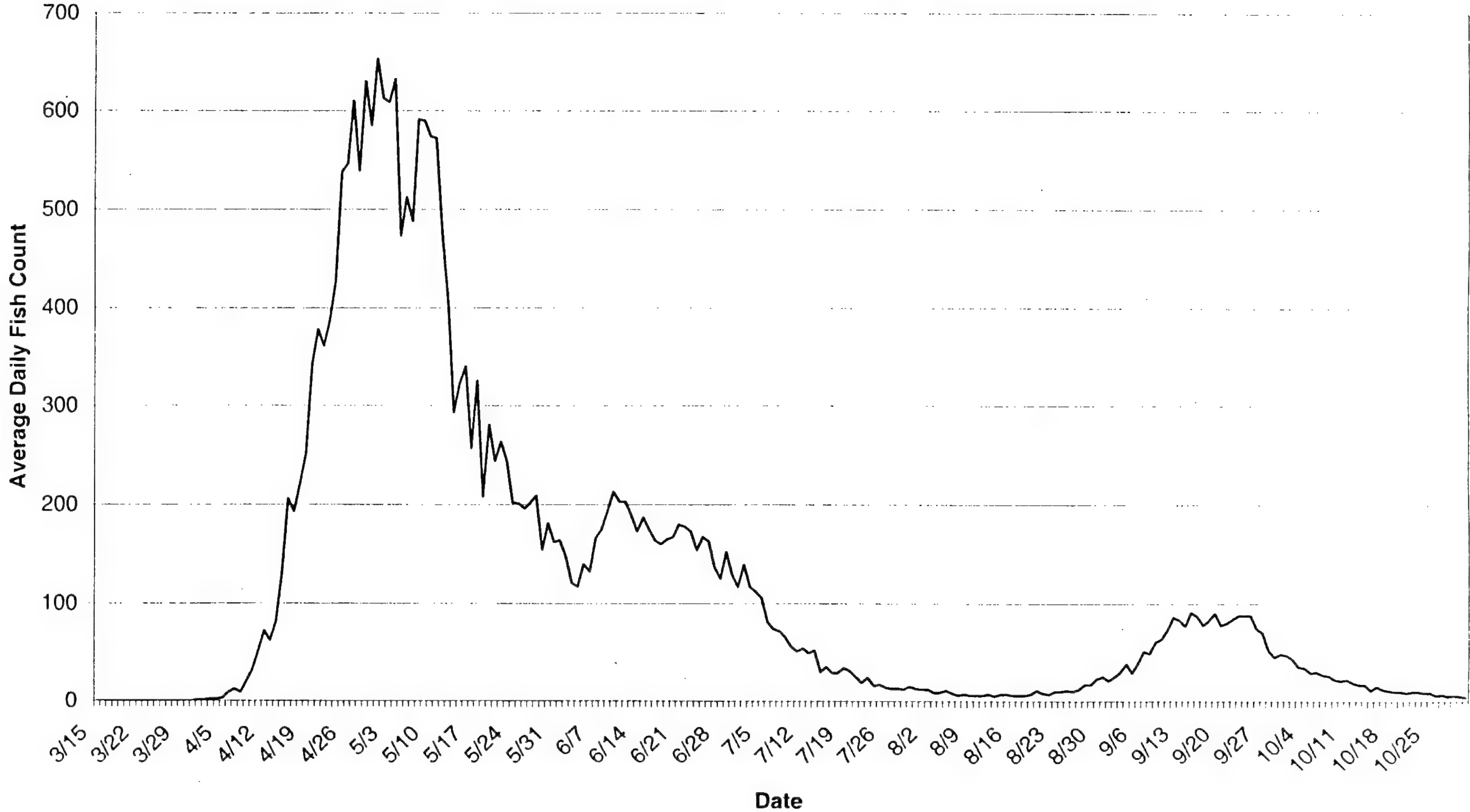

Figure 5-2. Adult Chinook Salmon Passage Dates at Ice Harbor Dam, 1977 to 1997

through May, while Grande Ronde River fish pass Bonneville Dam in April and May (Howell et al., 1985). Summer chinook destined for the Snake River enter the Columbia River in June and July. Spring chinook begin to enter the Snake River in April. Figure 5-2 shows the average daily numbers of adult chinook counted at Ice Harbor Dam for the past 20 years. The official dates set for the spring chinook run at Ice Harbor Dam are April 1 through June 11. Adult spring chinook enter the Clearwater River System from April through July, with the peak of migration in May (Nez Perce Tribe and IDFG, 1990). The Salmon River Basin supports several populations of spring and summer chinook that enter the system from April through September (IDFG et al., 1990).

Spawning can occur from late July through September with the greatest activity from mid-August through mid-September. Spring chinook typically spawn earlier and in higher elevation streams than summer chinook. Summer chinook spawn in medium-size, middle-elevation tributaries of the major Snake River tributaries. In streams where both spring and summer chinook salmon occur, spring chinook generally spawn earlier and at higher elevations than summer chinook (Matthews and Waples, 1991). Summer chinook typically spawn from August through October with the peak of spawning during September. Spring chinook fry emerge from November to April in the Salmon River Basin and from February to April in the Clearwater Basin. Summer chinook fry emerge from late March through mid-June. Juvenile spring and summer chinook salmon typically rear in tributary streams for a year before migrating to sea the following spring.

Downstream migration of most wild spring and summer chinook occurs from early April through late July. Small numbers of wild spring and summer Chinook continue to pass Lower Granite Dam until late July. The arrival times at Lower Granite Dam of chinook smolts from different tributaries varies. Achord et al. (1996) noted that wild summer chinook salmon generally arrived in large numbers before hatchery fish. The peak time of arrival for wild summer chinook at Lower Granite Dam occurred in April. Wild spring chinook arrive at Lower Granite Dam at different times depending on their stream of origin. As a result, wild spring chinook arrive at Lower Granite Dam over an extended period of time while hatchery fish pass the dam in a shorter period. Hatchery reared spring chinook also pass Lower Granite Dam earlier than wild fish. Achord et al. (1996) observed peak passage of hatchery spring chinook from April 22 through 24 in each of 3 years of study. They found that the peak passage period for wild spring chinook occurred later and generally coincided with times of peak river flow at Lower Granite Dam.

Achord et al. (1996) found that wild summer chinook salmon from the Imnaha River arrive at Lower Granite Dam earlier in the year than any other fish. They also found that wild spring chinook from the East Fork Salmon River reached Lower Granite Dam early, while Upper Big Creek fish arrived last. Smolts from the South and Middle Forks of the Salmon River begin to arrive at Lower Granite Dam in early April and peak in late April and early May. Grande Ronde River smolts were reported to arrive at Lower Granite Dam from early May to late June with a peak in early June (Matthews et al., 1990). Figure 5-3 shows the time when hatchery and wild yearling spring and summer chinook arrive at Lower Granite Dam.

Information from PATH (1996), indicates that the survival of juvenile salmonids from the area of the head of Lower Granite Reservoir to Ice Harbor Reservoir (about 155 km or 96 miles) declined from the pre-1970 period to the post-1974 period. The PATH group concluded that they were "reasonably confident that the hydrosystem has contributed to decreased juvenile survival in the downstream corridor for Snake River stocks in the post-1974 period." The Corps' Technical Appendix A (1999) also found direct survival to below Bonneville Dam to decline sharply in the late 1960s and early 1970s. They note that the decline in migration survival paralleled the decline in SARs and the

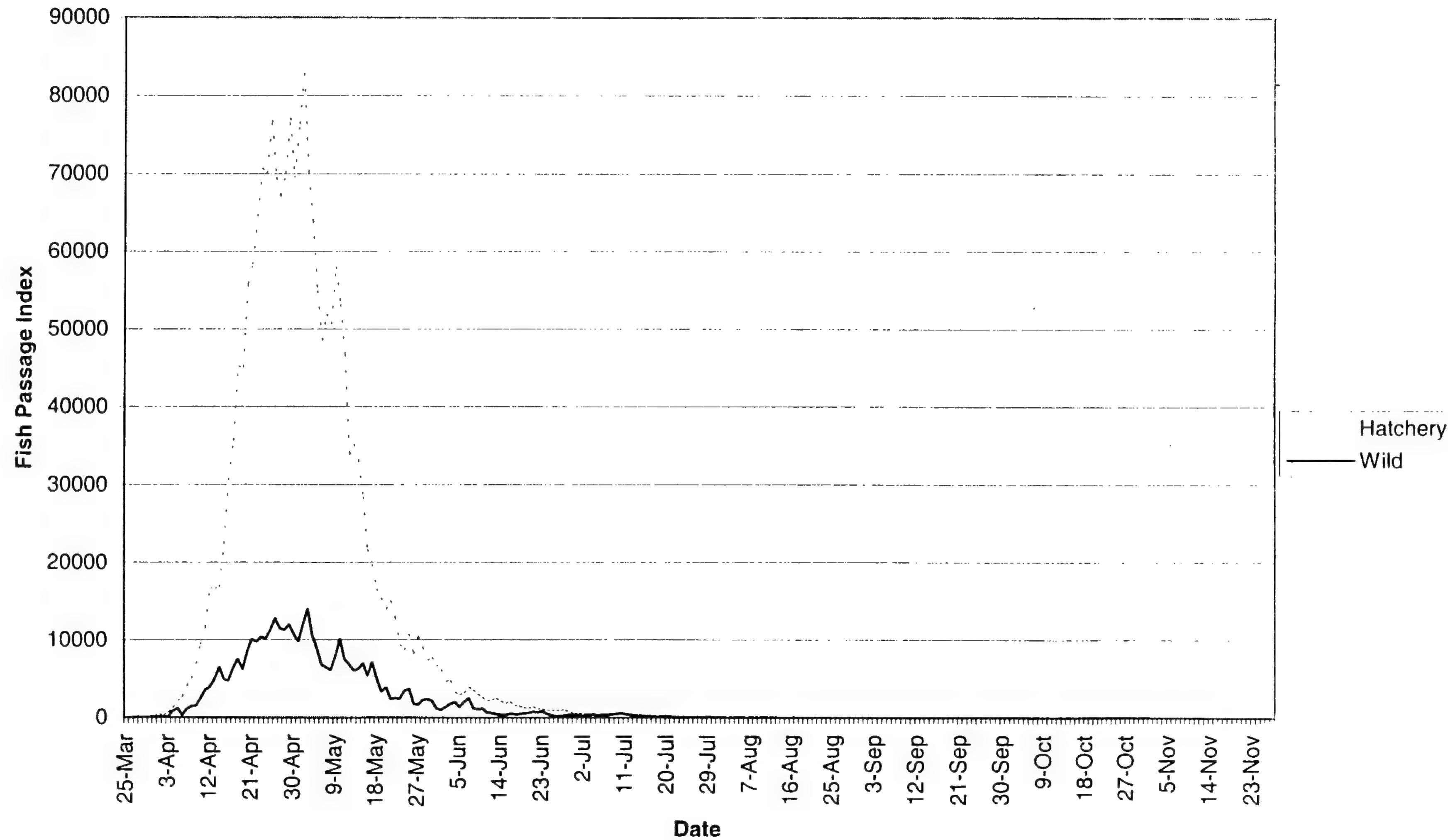

Figure 5-3. Timing of Yearling Chinook Salmon Arrival at Lower Granite Dam, 1985 to 1997

collapse of spring/summer salmon stocks. Subsequent improvements in transportation and bypass facilities during the 1980s have increased direct survival markedly (Corps' Technical Appendix A, 1999). However, SARs have not increased in concert with the improvements in direct survival, indicating that other factors must be keeping SARs low for spring/summer chinook salmon.

5.1.1.2 Fall Chinook

Fall chinook salmon returns to the Snake River declined after the construction of the Hells Canyon complex of dams (1955 to 1967) and the lower four Snake River dams (1962 to 1975). Adult fall chinook counts at Ice Harbor Dam dropped from 30,049 in 1962 to 1,864 in 1980 (Corps, 1996). An average of 461 (range = 78 to 742) natural adults passed upstream of Lower Granite Dam since 1990 (Lavoy and Mendel, 1996; Mendel and LaVoy, 1997).

Total counts at Ice Harbor Dam increased after the mid-1980s as a result of hatchery production from Lyons Ferry Hatchery and straying of fish from other areas, notably the Umatilla River. However, the 1981 through 1990 escapement for wild fall chinook salmon spawning in the Snake River and its tributaries upstream from Lower Granite Dam ranged from a high of 720 in 1982 to a low of 78 in 1990 (Waples et al., 1991). Figure 5-4 summarizes annual counts of fall chinook salmon at Ice Harbor Dam since 1962. The fall chinook counts depicted are for total numbers of fish observed and are not adjusted for fish that fell back over the dam and reascended the fishway or for fish that strayed from other river systems. The actual escapement of Snake River fall chinook would, therefore, be lower than the total count.

The core area of fall chinook salmon production near Marsing, Idaho, was inaccessible to spawners after the completion of the Hells Canyon Complex of dams. The construction of the four lower Snake River dams further reduced the production potential of the Snake River by an estimated 5,000 fall chinook salmon spawners (NMFS and USFWS, 1972). Fall chinook salmon production upstream of Lower Granite Dam is currently limited to the mainstem Snake River between Hells Canyon Dam and Lower Granite Reservoir and the lower reaches of the Imnaha, Salmon, Grande Ronde, and Clearwater rivers. Estimates of maximum sustainable production for the available spawning habitat in the mainstem Snake River range from 4,800 to 7,140 adults (Irving and Bjornn, 1981; Connor, 1994; Schaller and Cooney, unpublished report). Maximum sustainable production was estimated at 12,410 adults for the lower Clearwater River (Connor, 1994). Limited spawning has also been recorded in the tailraces of Lower Granite and Little Goose dams (Dauble et al., 1996). Spawning may also occur in the tailrace of Lower Monumental Dam.

Hatchery fish now comprise a large percentage of the fall chinook salmon that return to the Snake River and are estimated to contribute more than 47 percent of the Snake River escapement (Myers et al., 1998). Lyons Ferry Hatchery fall chinook were originally derived from fish within the distinct population (technically known as an evolutionarily significant unit) for the Snake River. Lyons Ferry Hatchery has been the main hatchery facility for fall chinook in the Snake River since 1984.

Adult fall chinook salmon enter the Snake River from August through November. The official passage dates for fall chinook at Ice Harbor Dam extend from August 12 to November 30. Since 1975, adult fall chinook salmon have passed Ice Harbor Dam during the months of August (12 percent of total), September (67 percent of total), and October (26 percent of total) (Corps, 1996). A small percentage of adults are counted passing Ice Harbor Dam in November and December. There has likely been little change in the time of fall chinook upstream migration as a result of the four lower Snake River dams.

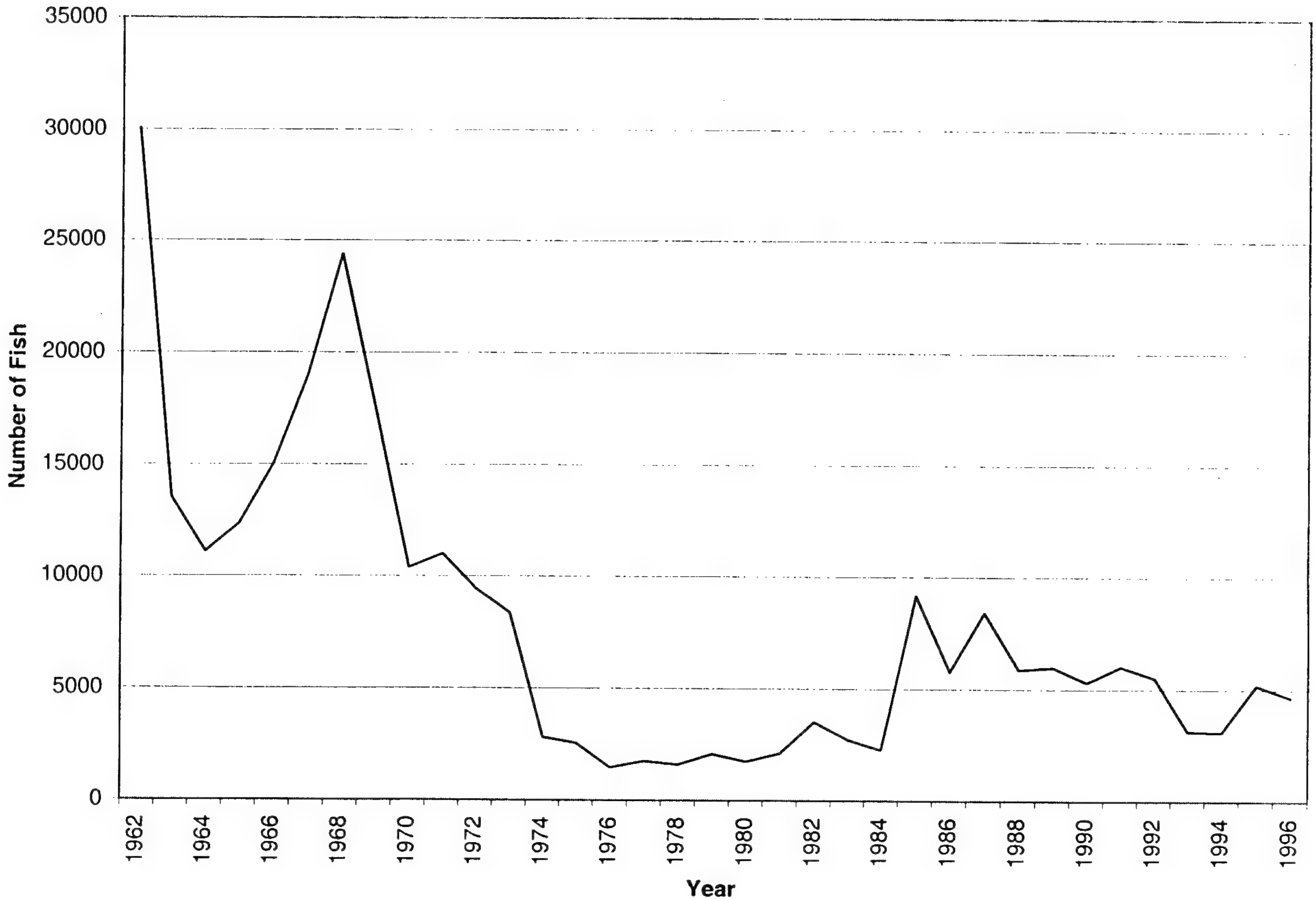

Figure 5-4. Annual Counts of Adult Fall Chinook Salmon at Ice Harbor Dam, 1962 to 1996

Because spawners were denied access to the core area of historic production by the Hells Canyon complex of dams, spawning now occurs only in the margins of the historic range. Intensive redd surveys have been conducted by an interagency/Indian team upstream of Lower Granite Dam since 1988 (Garcia, 1998). Between 1988 and 1997, 58 percent, 2 percent, 1 percent, 14 percent, and 25 percent of the redds counted were observed in the Snake, Imnaha, Salmon, Grande Ronde, and Clearwater rivers, respectively. Since 1993 there has been an increase in the proportion of redds counted in the Grande Ronde and Clearwater rivers. Published redd count data collected before 1975 for these current spawning areas are too incomplete to compare to redd counts made after 1988.

Since 1988, spawning has occurred from late October to early December (Garcia, 1998). In the Snake River the majority of spawning occurs in the first two weeks of November. In 1997 and 1998, there was a trend towards October spawning in the Grande Ronde and Clearwater rivers. Comparisons between pre-dam and post-dam spawn timing for fall chinook salmon cannot be made because of incomplete count data for the pre-dam period.

Water temperatures near Marsing, Idaho, where fall chinook formerly spawned before the dams were constructed, were warmer during the period of egg incubation than in the areas currently used for spawning (Connor et al., 1997). Consequently, embryo development now takes longer and present-day fry emerge later than their historic forebearers. From 1995 to 1998, the median dates of fry emergence in the Snake River upstream of the Salmon River confluence ranged from April 22 to April 30 (W.P. Connor, USFWS, unpublished data). The Salmon River cools the Snake River downstream of the confluence (Connor et al., 1993), so emergence is later in this reach (1992 to 1998 range of medians = April 16 to May 18) (W.P. Connor, USFWS, unpublished data) than it is upstream. The temperature regime of the Clearwater River is the coldest of the primary spawning areas used today, even though its winter thermal regime has been warmed by water released from Dworshak Dam (Connor, 1989; Arnsberg et al., 1992; Connor et al., 1997). The median dates of emergence in the Clearwater River from 1993 to 1995 ranged from May 28 to June 12 (W.P. Connor, USFWS, unpublished data).

The rearing period of fall chinook salmon can generally be described using beach seine catch data reported for 1995 (Connor et al., 1997). The median date of capture for parr rearing in the Snake River upstream of the Salmon River was May 28; in the Snake River downstream of the Salmon River confluence, it was June 4; and in the Clearwater River, it was July 2. These rearing periods are later than those reported historically (refer to Section 4.1.1, Fall Chinook Salmon) as a result of later fry emergence dates.

Displacement from the core production area and migration delays caused by the four lower Snake River dams have resulted in a late and protracted passage period through the lower Snake River for subyearling fall chinook salmon smolts. Subyearling smolts currently pass Lower Granite Dam primarily in June, July, and August (W.P. Connor, USFWS, unpublished data; Fish Passage Center of the Columbia River Basin Fish and Wildlife Authority, unpublished data). A small percentage of the run continues to pass Lower Granite Dam up until November. This time of passage contrasts to the historic population which passed out of the Snake River by July (refer to Section 4.1.1, Spring and Summer Chinook Salmon). Figure 5-5 shows the time when wild and hatchery juvenile fall chinook arrive at Lower Granite Dam, based on fish passage indices.

Fall chinook salmon smolts likely begin to migrate seaward at fork lengths similar to their historic counterparts. During their protracted residence in Lower Granite Reservoir, however, the smolts continue to grow at a rate of 1.4 mm (0.06 inch) per day (W.P. Connor, USFWS, unpublished data).

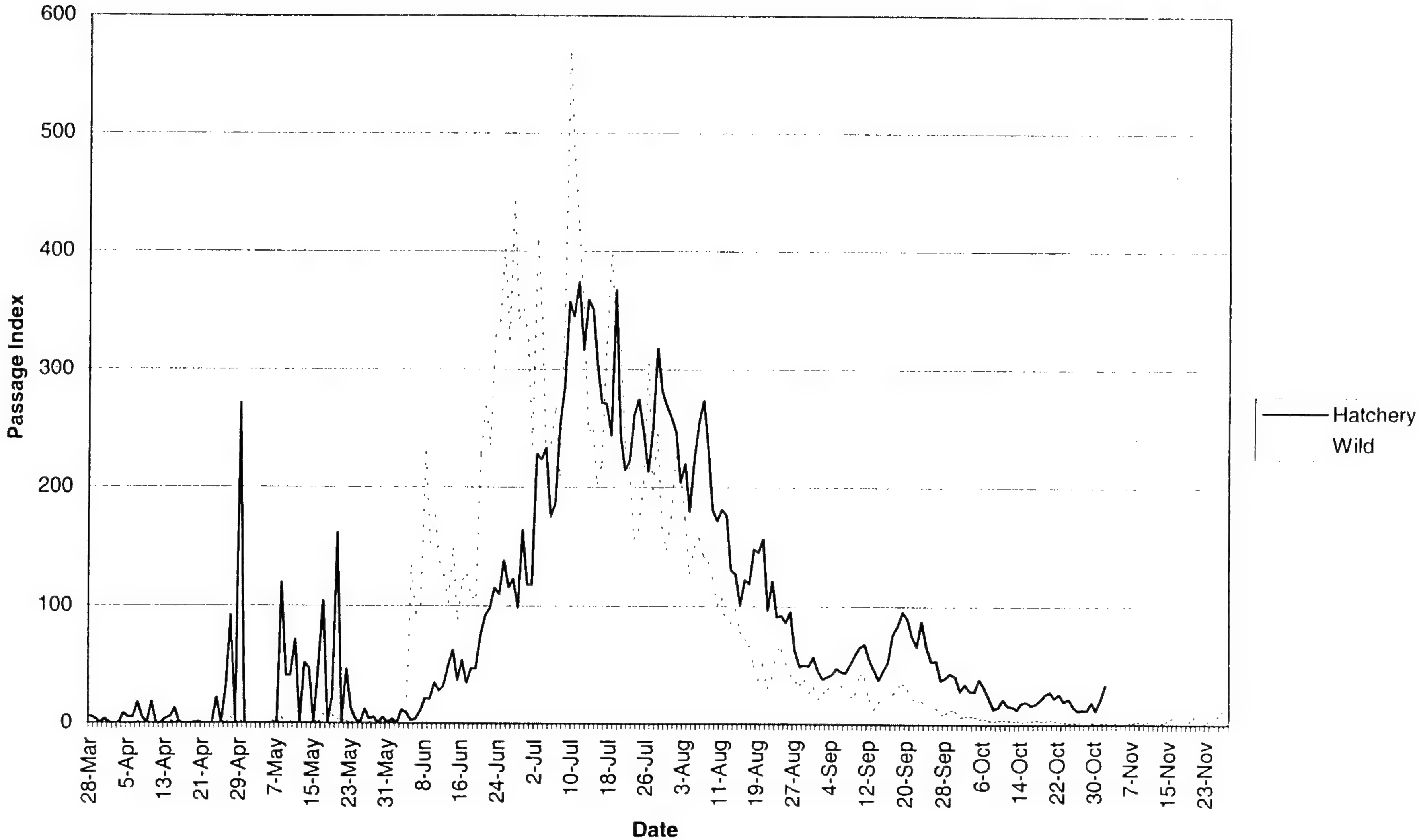

Figure 5-5. Subyearling Chinook Salmon Timing at Lower Granite Dam, 1987 to 1997

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Fork length of smolts recaptured at Lower Granite Dam (river mile 108) averaged 127 mm (5.0 inches) in 1991, 126 mm (5.0 inches) in 1993, 132 mm (5.2 inches) in 1994, and 142 mm (5.6 inches) in 1995 (W.P. Connor, USFWS, unpublished data) compared to the fork length range of 93 to 103 mm reported for fish trapped at river mile 82 in 1954 and 1955 (refer to Section 4.1.1, Fall Chinook Salmon).

Juvenile fall chinook are exposed to warmer water temperatures than they were historically (refer to Section 4.1.1, Fall Chinook Salmon) because a large proportion of the run is still in the Snake River in July and August. For example, water temperatures in Lower Granite Reservoir when smolts were emigrating averaged more than 21.1°C (70°F) in 1992, 17.5°C (63°F) in 1993, 19.6°C (67°F) in 1994, and 17.6°C (63°F) in 1995 (D.H. Bennett, U. of Idaho, unpublished data). In 1992, a water temperature of 24.3 to 25.2°C (76 to 77°F) was lethal to chinook salmon for five consecutive days in late June (Connor et al., in preparation).

Delayed migration is also one possible consequence of impounding downstream migration routes of subyearling fall chinook salmon (Haas, 1965). While only a small percentage of fall chinook salmon that are PIT-tagged upstream of Lower Granite Dam are detected migrating seaward as yearlings (Connor et al., 1996, 1997, in press), yearling migrants may be important to adult returns, especially in rivers that produce late emerging fry such as the Clearwater River (Arnsberg and Statler, 1996). One third of the carcasses collected on the spawning grounds of the Grande Ronde and Clearwater rivers in 1996 and 1997 had migrated seaward as yearlings, based on scale pattern analysis (Sneva, 1998).

The shift in the timing of seaward migration and passage delays in the lower Snake River reservoirs have led to low survival of fall chinook salmon smolts as they migrate downstream. Connor et al. (in preparation) reported detection rates for subyearlings that were PIT-tagged in the Snake River. The detection rates were 5.1 percent in 1992, 19.1 percent in 1993, 8.4 percent in 1994, and 30.4 percent in 1995. Survival probability estimates (Cormack, 1964; Jolly, 1965; Seber, 1965; Burnham et al., 1987) were also published for natural subyearling fall chinook salmon in 1995. Survival from release to the tail race of Lower Granite Dam for natural subyearling fall chinook salmon ranged from 17.5±6.0 percent for fish in the lower Clearwater River to 67.6±5.0 percent for fish in the Snake River upstream of the Salmon River confluence (Connor et al., 1997). Survival for the same fish from release to the tail race of Lower Monumental Dam was 4.8±1.2 percent for fish from the Clearwater River and 44.6±5.1 percent for fish from the Snake River upstream of the Salmon River confluence (Smith et al., 1997b).

Hydroelectric dam construction is the primary factor responsible for the marked decline in Snake River fall chinook salmon abundance between 1955 and 1991. The Hells Canyon complex of dams displaced and eliminated the core population of Snake River fall chinook salmon. Consequently, existing production is dependent upon fish that spawn in the margins of the historic range. These fish emerge and begin seaward migration later than the core population would have historically. The timing of emergence and smoltification have changed little since the construction of the four lower Snake River dams, except in the lower Clearwater where fry emerge earlier than historically (Connor et al., 1997). Before the lower Snake River dams were constructed, habitat within the margins of the historic range likely had the potential for viable fall chinook salmon production. However, the lower Snake River dams have delayed seaward migration of smolts, thereby exposing them to water temperatures, flows, and levels of predation that were not experienced by their pre-dam counterparts.

5.1.2 Sockeye Salmon

Presently, Redfish Lake in the Salmon River Basin supports the only remaining run of sockeye salmon in the Snake River System. This is the southernmost natural population of sockeye salmon in the world. Redfish Lake sockeye also make the longest migration and spawn at the highest elevation of any sockeye in the world (NMFS, 1995b). Sockeye salmon runs in the Snake River System have declined to critical levels at which they are nearly extinct. The number of adult sockeye counted at Ice Harbor Dam has fallen from over 1,000 in the 1960s to less than 100 in the 1980s to fewer than 10 during much of the 1990s. Figure 5-1 shows total annual counts of adult sockeye salmon at Ice Harbor Dam since 1962.

The drastic decline in adult sockeye returns led to the 1991 NMFS listing of Snake River sockeye as endangered. The greatest decline in Snake River sockeye populations occurred before the construction of the lower Snake River dams. However, counts of sockeye salmon have continued to decline since the lower Snake River dams were built. Early losses were attributed to overharvest, construction of dams at upstream sites, and irrigation diversions. Fisheries management decisions during the 1960s resulted in blockage of access to some of the lakes that still produced sockeye and chemical treatment of lakes to eradicate sockeye in favor of resident species of fish.

Adult sockeye salmon enter the Columbia River from June through August with peak passage at Bonneville Dam occurring in June. Snake River sockeye pass Bonneville Dam from June through July and pass Lower Granite Dam from June 25 to August 30 (IDFG, 1990). Sockeye migrate upstream and usually arrive at Redfish Lake from mid-July through August and spawn in September and October. Fry emerge in the spring, and juveniles may rear in Redfish Lake for 1 to 3 years (Bell, 1991). Sockeye smolts emigrated to the ocean from the Salmon River system from late April through mid-May from 1955 through 1966 (Bjornn et al., 1968). Mains and Smith (1964) reported catching migrating sockeye salmon in the Snake River between May 17 and June 8 during sampling in 1955.

Smolt mortality at mainstem hydroelectric dams has been cited as primary causes for the decline of sockeye salmon in the Snake River Basin (TAC, 1997). Recovery of sockeye salmon will require improved survival of smolts through the Snake and Columbia river systems during their downstream migrations.

The level of mainstem harvest of adult returns declined from an average of 40 percent of adults that returned to the Columbia River mouth before 1974 to 9 percent after that time (Corps' Technical Appendix A, 1999) citing ODFW and WDFW, 1998). As dam effects on juvenile and adult migrants increased, the level of harvest on adult returns declined (Corps' Technical Appendix A, 1999). No commercial harvest of sockeye salmon has been allowed since 1988, and the 1996-1998 Management Agreement allows impacts on only 1 percent of the non-Indian commercial and recreational fisheries combined.

Fish passage remains cut off to all former Snake River sockeye habitat except the Stanley Basin (Corps' Technical Appendix A, 1999), the location of Redfish Lake. Agricultural diversions are listed as a cause of the sockeye salmon's decline from all Stanley Basin lakes (Corps' Technical Appendix A citing Chapman et al., 1990). Aside from causing dewatering of some migrational reaches, many of the diversions in the Stanley River subbasin streams remained unscreened until the 1970s, and some are still not screened. Conditions on the mainstem Salmon River are improving for juvenile sockeye salmon through a screen replacement and construction program funded through the Mitchell Act (Corps' Technical Appendix A, 1999). Also, the U.S. Forest Service purchased water rights (with Bonneville Power Authority [BPA] funds) to enhance instream flows, and the

U.S. Bureau of Reclamation (BOR) has been addressing agricultural diversion problems on the Salmon River.

The Corps' Technical Appendix A (1999) estimated a 22 percent loss of sockeye salmon migrating upstream from Bonneville Dam to Lower Granite Dam. This loss was based on a 1997 study of 800 radiotagged sockeye and was based on the assumptions that 1) the per-dam loss rate of adult Snake River sockeye salmon in the lower Columbia River is similar to that of individuals from the mid-Columbia stocks and 2) the per-dam loss rate of adult Snake River sockeye salmon through the lower Snake River would be similar to that measured for mid-Columbia sockeye salmon in the lower Columbia River.

Downstream migration of sockeye salmon smolts occurs mainly during the late spring and summer. While pre-dam reports indicated that sockeye smolt migration occurred in May and June, recent monitoring of PIT- tagged fish from Redfish Lake shows that those fish pass Lower Granite Dam from mid-May through mid-July. Index counts show that wild sockeye pass Lower Granite Dam from March to early September and outmigration continues into November. Figure 5.6 shows the index counts for sockeye salmon arrival at Lower Granite Dam from 1985 to 1997. However, some of these fish may be kokanee that originated from Dworshak Reservoir. For comparison, index counts for Rock Island Dam on the mid-Columbia River show sockeye passage occurring from mid-April to mid-July. Warmer water temperatures and lower river flows during the summer may be contributing to poorer conditions for juvenile sockeye migration and lower survival of smolts that migrate through the lower Snake River reservoirs during that time.

5.1.3 Coho Salmon

During the 1960s, counts of adult coho salmon at Ice Harbor Dam ranged from a low of 320 in 1965 to 6,227 in 1968. Adult coho counts declined from 3,636 in 1970 to 398 in 1979 and continued to fall until no fish were counted in 1986. Wild coho salmon in the Snake River were declared extinct in 1986 (IDFG, 1992). Figure 5-1 shows annual passage of coho salmon at Ice Harbor Dam since 1962.

To restore coho populations in the Snake River System, the Nez Perce Indians have proposed reintroducing coho salmon into the Clearwater River through artificial propagation and release of acclimated smolts to develop a broodstock program. In 1995, the Nez Perce Indians planted 400,000 coho fingerlings into the Clearwater River Basin. These fish were obtained from surplus coho that returned to the Cascade and Eagle Creek hatcheries in 1994. The long-range goal would be to expand this program and release juvenile coho into selected streams that formerly supported coho salmon and that have existing habitat to support natural production of these fish.

In 1997, adult and jack coho salmon returned to the Snake River, presumably from the outplantings of parr. Counts at Lower Granite Dam in 1997 totaled 94 adults and 10 jacks. Returning adult coho were recorded at Ice Harbor and Lower Granite dams from late September through early November.

The Nez Perce Indians have proposed releasing 770,000 coho smolts, 450,000 parr, and 10,000 fry into the Clearwater River System in 1998 (Bureau of Indian Affairs, 1998). Smolts would originate from Bonneville Fish Hatchery and Willard National Fish Hatchery (NFH). Fish to be released as parr and fry would be obtained from Bonneville Hatchery. Smolts from Bonneville Hatchery stock would be expected to begin their outmigration immediately after their release. Peak passage of these fish is expected in the last 2 weeks in May. Smolts from Willard NFH would be released in

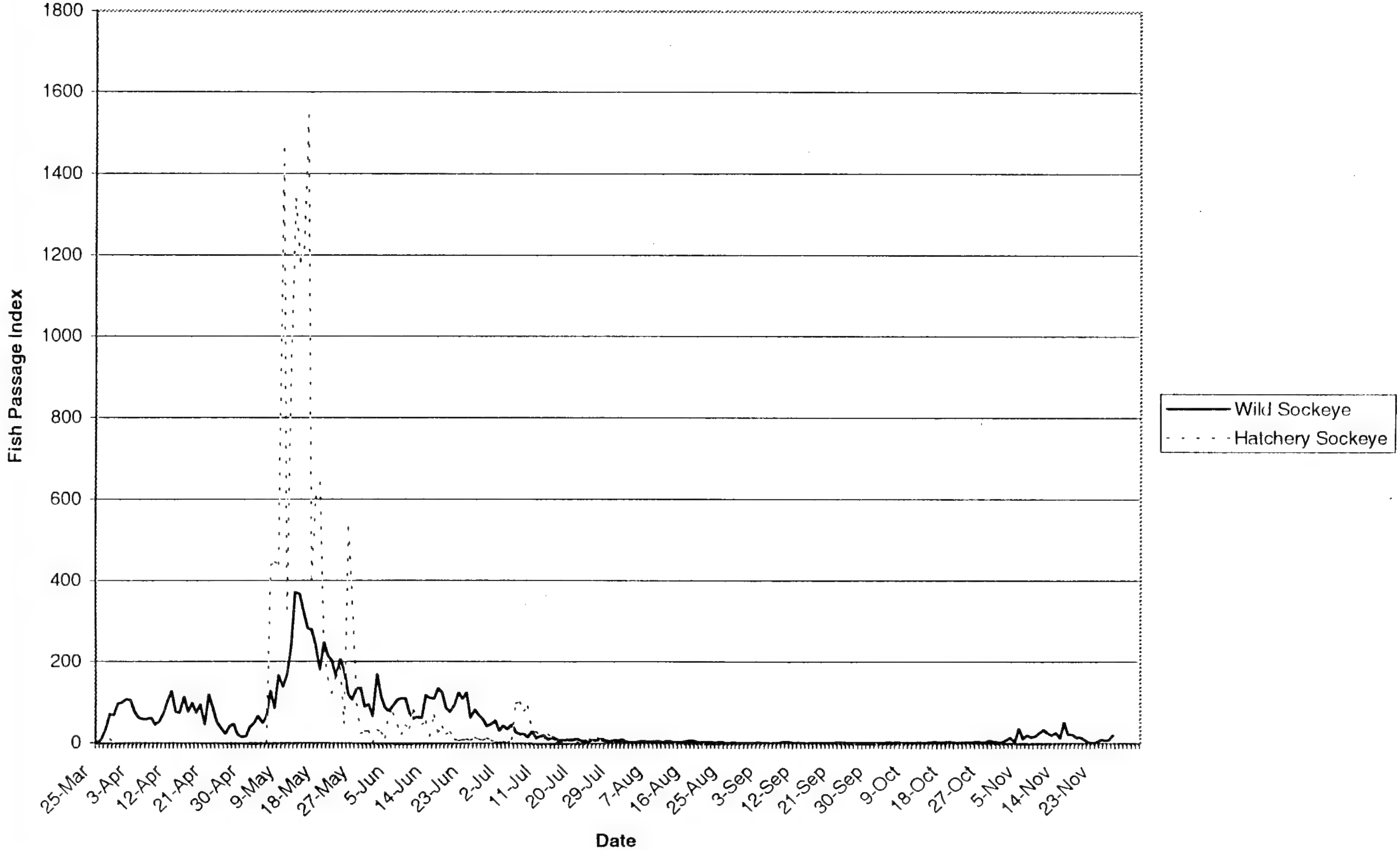

Figure 5-6. Timing of Juvenile Sockeye Salmon Arrival at Lower Granite Dam (1985 to 1997)

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mid-March and would migrate shortly after their release. These fish would be expected to pass Lower Granite Dam from the last week in March through the first week in April. Parr and fry would rear in the tributary streams before migrating. Coho salmon parr that were planted in 1995 began their outmigration in late May. Parr and fry that are outplanted in 1998 are expected to migrate seaward in late May (Bureau of Indian Affairs, 1998). Figure 5-7 indicates the passage times for juvenile coho salmon at Lower Granite Dam.

5.1.4 Steelhead

The average return of wild steelhead to the Snake River basin declined from about 30,000 to 80,000 adults in the 1960s through mid-1970s to 7,000 to 30,000 in recent years (Corps' Technical Appendix A, 1999). The sharp decline in steelhead numbers during the early 1970s parallels the similar sharp decline in spring/summer chinook salmon populations during the same period. Adult returns of steelhead fluctuated in the 1980s and 1990s, with the 1990 to 1991 run being less than half of the 1989 to1990 run (IDFG, 1992) (Figure 5.8). The total return of steelhead to the Snake River has been relatively high in recent years. However, the return of wild steelhead has declined during the same period. NMFS listed wild Snake River steelhead as threatened in August 1997.

The average escapement of steelhead past Lower Granite Dam for run years 1985/1986 through 1995/1996 was about 16,200 wild and 72,800 hatchery fish (TAC, 1997). The A-run averaged about 64,800 fish (52,400 hatchery and 12,400 wild), while the B-run averaged about 24,200 fish (20,400 hatchery and 3,900 wild) annually during this period. Total adult steelhead escapement to Lower Granite Dam has shown an increasing trend since 1975. However, escapement of wild steelhead has declined since 1985. The overall adult steelhead escapement trend has declined since 1985, and annual counts have fluctuated greatly. Figure 5-8 shows total and wild escapement of Snake River steelhead from 1985/86 to 1995/96, based on counts at Lower Granite Dam.

Densities of juvenile steelhead, which IDFG uses as an index of natural production, have declined to about 15 percent of the habitat-based production potential. Densities of wild A-run juvenile steelhead have ranged from 33 to 85 percent of carrying capacity at index sites, while B-run juvenile densities have ranged between 9 and 16 percent of carrying capacity. The trend for A-run fish has been downward, while B-run juvenile densities have remained low, but relatively constant (TAC, 1997).

The following is excerpted from the Corps' Technical Appendix A (1999):

> *Sandford and Smith (manuscript submitted for publication) describe recent PIT-tag returns that indicate the SARs of steelhead smolts vary with route of passage through the hydrosystem. This suggests that post-Bonneville mortality is not equivalent for all fish migrating in-river and that the experience of a smolt passing through the hydrosystem, in part, determines the likelihood of survival. Possible mechanisms for this delayed mortality of both transported and non-transported fish, as a result of hydrosystem passage, have been proposed and are described in Marmorek et al. (1998a)."*
>
> *Snake River steelhead are not targeted by ocean fisheries and ocean harvest of steelhead is effectively non-existent. Columbia River harvest rates have varied as a function of run size. When wild Snake River steelhead abundance was relatively high in the 1960s and early 1970s, aggregate (i.e., combined hatchery and wild for all stocks) upriver steelhead harvest rates ranged from 23 to 40 percent (ODFW and WDFW 1998). As abundance declined through the mid-1970s and partially rebuilt during the early 1980s, aggregate harvest rates*

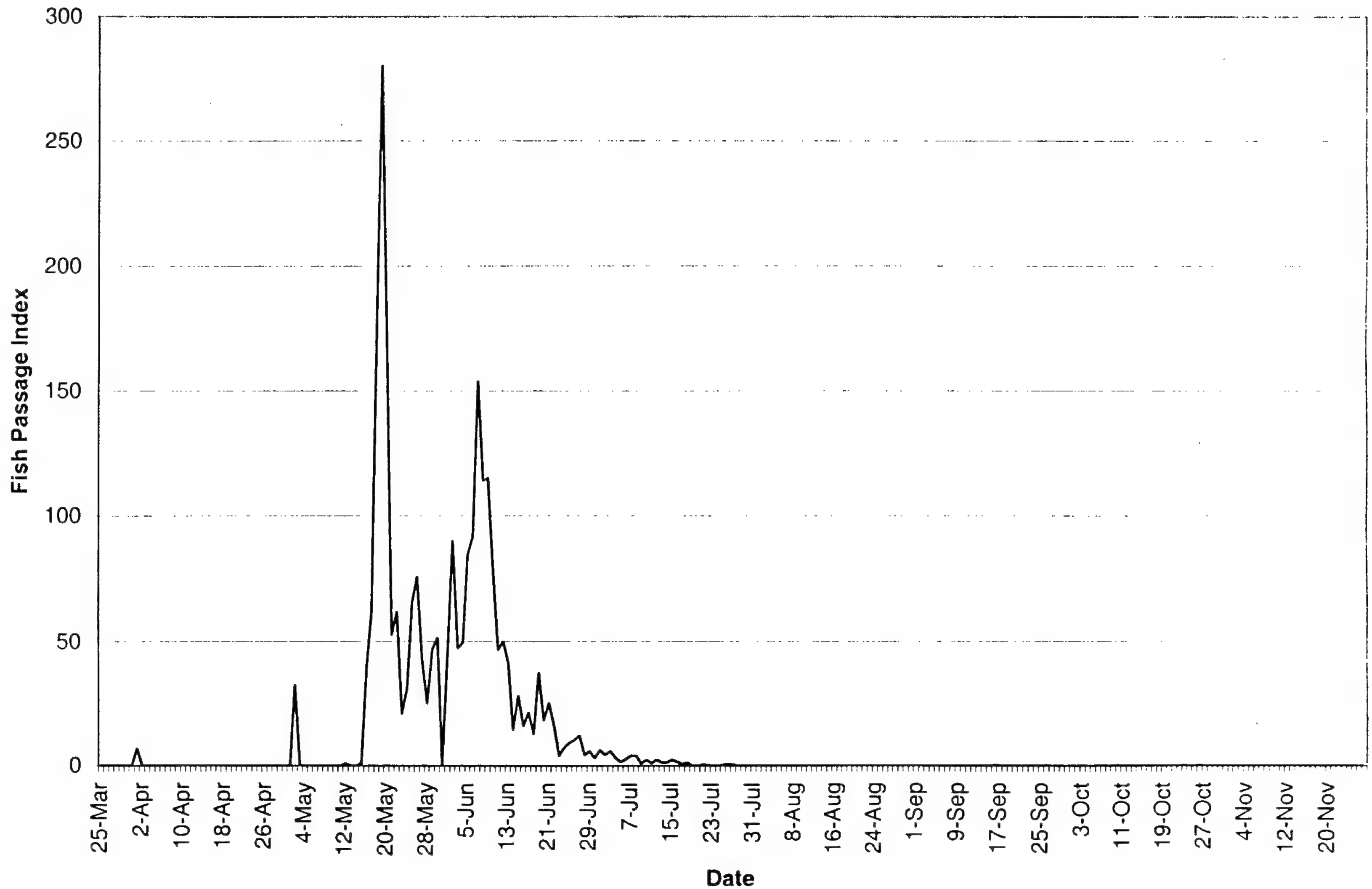

Figure 5-7. Timing of Juvenile Coho Salmon Arrival at Lower Granite Dam

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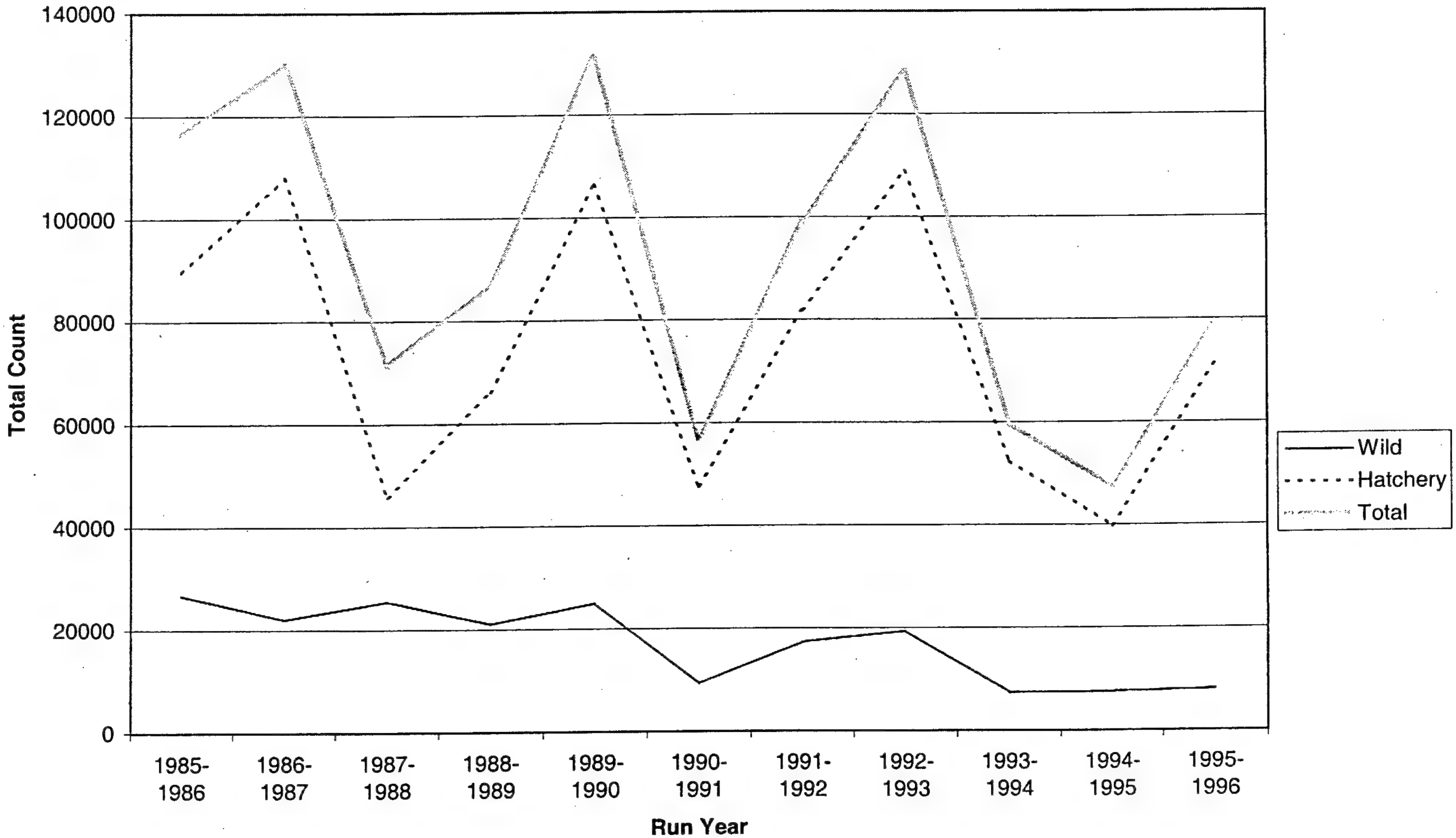

Figure 5-8. Total Adult Steelhead Counts at Lower Granite Dam for Run Years 1985/86 to 1995/96

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dropped, ranging from approximately 6 to 13 percent. From 1984 through 1993 aggregate harvest rates increased to 16 to 25 percent, and then dropped again to 10 to 11 percent since 1994. This description of aggregate harvest rates is representative of mainstem harvest of wild A-run steelhead, but underestimates the wild B-run mainstem harvest rates, which have ranged from approximately 25 to 47 percent since the mid-1980s (TAC 1997).

In general, trends in harvest rates do not appear to explain trends in abundance. In particular, because both harvest rate and abundance declined in the early 1970s, it is unlikely that harvest rate was a significant cause of that decline. The absence of a negative association between the Snake River steelhead harvest rate and abundance does not mean that harvest is unimportant; it simply means that fluctuations in steelhead numbers are not well-explained by fluctuations in harvest rates.

Hatchery programs in the Snake River Basin have been relatively successful at producing returns of adult hatchery steelhead. Hatchery steelhead from the Snake River now comprise a major portion of the summer steelhead returning to the Columbia River. Hatchery fish were found to make up about 86 percent of the adult steelhead counted at Lower Granite Dam in recent years (Busby, et al., 1996). Since 1988, Snake River Basin hatcheries have produced from 9 to 11.3 million juvenile steelhead annually. In 1997, hatcheries released about 9.95 million steelhead into all of the major stream systems in the Snake River Basin. This was about 83 percent of all the anadromous fish that were released into the Snake River Basin that year (Fish Passage Center [FPC], 1998). Most of the fish released into the Clearwater River System are B-run fish raised at Dworshak NFH while mostly A-run fish are released into other Snake River tributaries. Figures 5-9 and 5-10 depict the recent returns of hatchery and naturally produced A- and B-run steelhead to the Snake River, based on counts of adult fish at Lower Granite Dam.

The total return of adult steelhead to the Snake River has increased since the mid 1970s. However, hatchery fish have provided this increase. From 1984 through 1991, wild or natural fish constituted from 13 to 37 percent of the total return of adult Snake River steelhead (IDFG, 1992). This percentage has remained low, even though all legal harvest of wild/natural steelhead in the Snake River Basin has been stopped.

A-run steelhead may migrate up the Columbia River and begin to enter the Snake River as early as July. However, upstream migration may be slowed by high water temperatures in the Columbia River, and both A- and B-run steelhead may intermingle by the time they reach the Snake River. Most steelhead begin to enter the Snake River in the fall, although some of the run overwinters in the Columbia River near McNary Dam. After entry into the Snake River, some steelhead overwinter in the lower river, while others migrate into the larger tributaries such as the Clearwater, Salmon, and Grande Ronde rivers. Steelhead reportedly do not enter the Tucannon River until fall when water temperatures drop (WDFW et al., 1990b).

Steelhead spawning occurs as early as February for Tucannon River steelhead (WDFW et al., 1990b) and continues into late June for wild stock Rapid River fish (IDFG et al., 1990). Spawning also occurs in lower reaches of several smaller tributaries of the Snake River, including Deadman, Meadow, Penawa, Almota, Steptoe Canyon, Tenmile, and Couse creeks (Howell et al., 1985 in WDFW et al., 1990b).

Wild steelhead fry emerge from the gravel from April through September and rear in tributaries for 1 to 3 years, with most rearing for 2 years, before migrating to sea. Steelhead smolts usually migrate out of the Snake River System from March through June. Steelhead passage at Lower Granite Dam

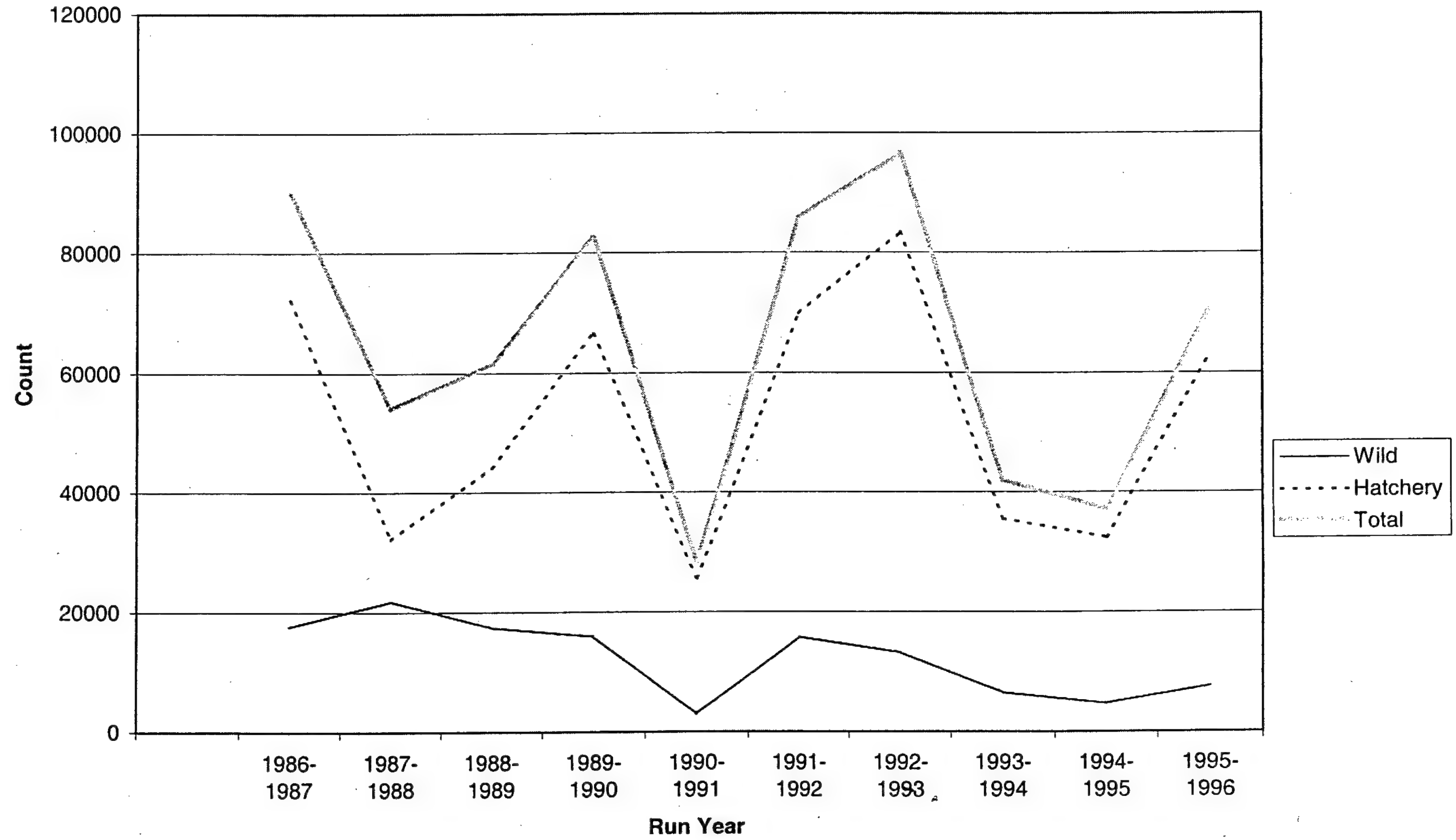

Figure 5-9. Counts of Wild and Hatchery A-run Steelhead at Lower Granite Dam for Run Years 1986/87 to 1995/96

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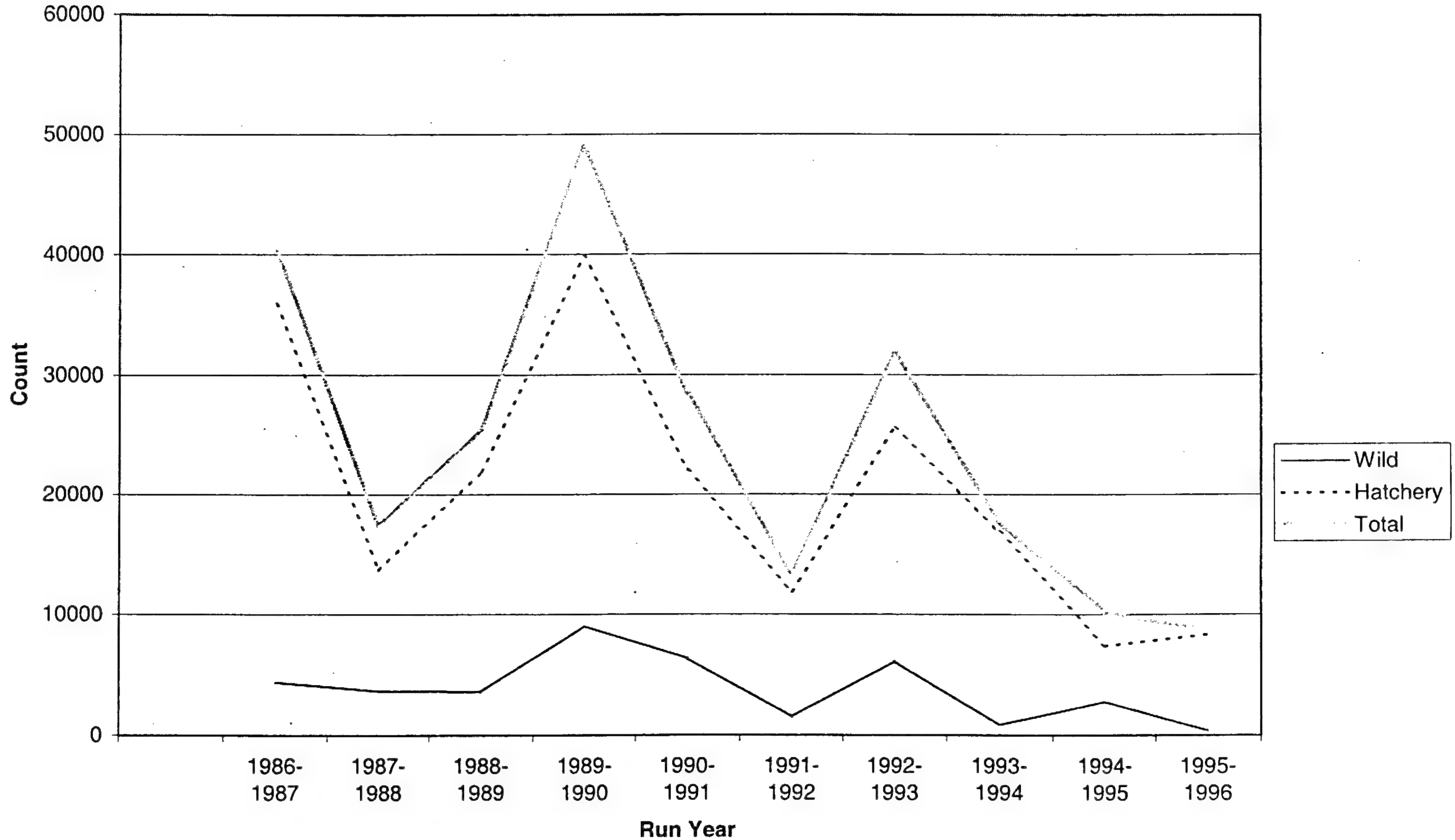

Figure 5-10. Counts of Wild and Hatchery B-run Steelhead at Lower Granite Dam for Run Years 1986/87 to 1995/96

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typically occurs from the latter part of March through early June. The average dates when 10 percent and 90 percent of all steelhead smolts passed Lower Granite Dam from 1985 through 1994 were April 29 and May 30, respectively (FPC, 1997). Wild steelhead passage dates at Lower Granite Dam for the 10 percent and 90 percent totals of the smolt migration ranged from April 14 in 1996 to May 30 in 1990. Figure 5-11 shows the timing of steelhead smolt arrival at Lower Granite Dam.

5.1.5 Pacific Lamprey

The current distribution of Pacific lamprey in the Columbia River and tributaries extends to Chief Joseph Dam and to Hells Canyon Dam in the Snake River. Both dams lack fishways and limit distribution of migrating fish. Lamprey numbers decreased significantly as the number of dams and development increased within the Columbia and Snake rivers. Hammond (1979) stated that lamprey numbers, along with those of the anadromous salmon, have declined since construction of the hydroelectric dams on the Columbia River system. Close et al. (1995) note that counts of lamprey at all Columbia and Snake river dams have shown a downward trend from the 1960s to the present. They no longer exist in numerous tributaries. Only minimal information is currently available for this species in many areas, and exact numbers are not available at any counting locations. No survey has been undertaken to examine the actual distribution throughout the Columbia River drainage.

Close et al. (1995) noted that grates and velocity barriers designed to inhibit the passage of lamprey were built in the fish ladders of some dams. These obstructions forced lamprey to use suction to climb the moist walls of the fish ladders to reach the next higher pool. These barriers were cited as potentially increasing the exhaustion rate of adult lamprey, which would decrease their migration rates.

5.1.6 American Shad

The American shad is a highly migratory, anadromous species. Males mature when 3, 4, or 5 years old, and females mature when 4, 5, or 6 years old. Adult American shad enter the Columbia River estuary in late April. The peak upstream migration past lower Columbia River dams occurs in June. Spawning occurs from late June to late July at Bonneville Dam and farther upstream in the Columbia River. The peak of spawning varies slightly from year to year, depending upon water temperature and river flow. The extent of spawning areas in the Columbia River is not well documented. From the distribution and size of young-of-the-year, spawning seems to be opportunistic, occurring from the estuary to the upriver reservoirs. American shad may spawn at many different depths and over a variety of substrates. They seem to prefer areas of shallow water (flats), although they also spawn in deeper waters adjacent to shoals (Facey and Van Den Avyle, 1986). The tailraces below various dams appeared to be the main spawning ground, with the eggs dispersed downstream by current.

Larvae and young rear in the reservoirs. When about 10 cm (4 inches) long, they migrate to sea in the early winter after water temperatures decline. Downstream movement occurs from October through December. Most young shad pass Columbia River dams on their way downstream in late October and early November. As juveniles, they are preyed upon most heavily by gulls at the various dam tailraces. Young American shad are quite fragile; the stress of dam passage stuns or kills large numbers, making them easy prey for gulls. Gross observation with binoculars of feeding gulls at dam tailraces suggested that large numbers of juvenile American shad and juvenile fall chinook salmon may be eaten. There is some light to moderate predation by white sturgeon, northern pikeminnow, walleye, smallmouth bass, crappie, and salmon.

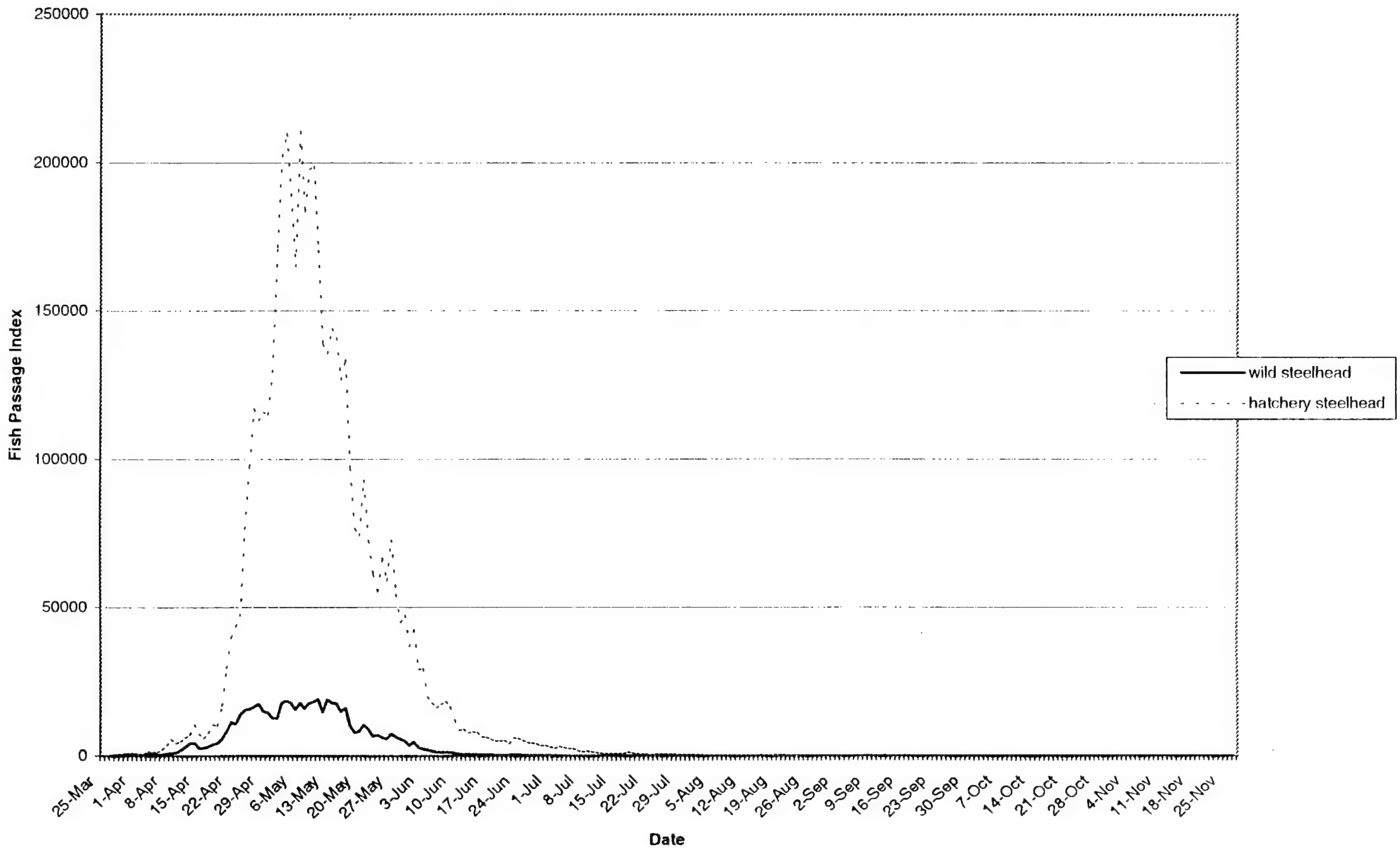

Figure 5-11. Timing of Juvenile Steelhead Passage at Lower Granite Dam (1985-1997)

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Commercial landings of American shad from the Columbia River have fluctuated between 21,200 fish in 1984 and 384,600 in 1946 (Washington Department of Fisheries and Oregon Department of Fish and Wildlife [ODFW], 1992). Despite dramatic increases in numbers of American shad in the river, the commercial fishery has declined for two major reasons: the lack of a consumer market and the concurrence of the American shad adult upstream migration with the upstream migrations of adult sockeye salmon, spring/summer and fall chinook salmon, and summer steelhead. It is practically impossible to manage a commercial fishery for American shad that would not also capture salmonids.

Long-term, detailed information is lacking concerning the life history of the American shad in the Columbia River. Even less is known about its ocean life history phase. It appears that the juvenile American shad outmigration overlaps the outmigration of spring/summer and fall chinook salmon in the reservoirs. In the estuary, American shad outmigrant timing appears to overlap with juvenile salmonid outmigrations. In these areas, juvenile American shad can use essentially the same food resources as the juvenile salmonids.

5.2 Resident Fish (Post-Dam)

Construction of the four lower Snake River reservoirs drastically altered the ecosystem of the Snake River (USFWS, 1994). The once dynamic riverine environment, subject to a wide range of spring floods, became a series of controlled impoundments. This led to a major shift in the biotic community, especially in fish populations (Bennett et al., 1983). Reduced current velocities, changes in bottom substrate, lowered dissolved oxygen, and increased water temperatures have favored cool and warmwater species, many of which are not native to the Snake River (Bennett et al., 1983; USFWS, 1994).

Since Ice Harbor Dam was completed in 1961, studies have shown a much higher fisheries loss than originally anticipated (USFWS and NMFS, 1972). High quality stream fisheries for smallmouth bass (*Micropterus dolomieui*), white sturgeon, and channel catfish in the lower Snake River have been converted to low-quality, reservoir-type fisheries with abundant populations of non-game species.

The lower Snake River reservoirs currently support a diverse fish fauna. Thirty-four resident species have been collected in these reservoirs from 1979 through 1993 (Annex A) (Bennett et al., 1997a; Bennett et al., 1997b; Bennett et al., 1995; Bennett et al., 1991; Bennett et al., 1988a; Bennett et al., 1988b; Bennett et al., 1983; Bennett and Shrier, 1986; Chipps et al., 1997; Dresser, 1996; Mullan et al., 1986; Shively et al., 1991). These include a mix of native riverine species and non-native species which are more typically associated with lake-like or lacustrine conditions (Bennett et al., 1983; Bennett and Shrier, 1986; Hjort et al., 1981; Mullan et al., 1986). Less than half of the species collected are native to the Snake River, including white sturgeon, salmonids (family Salmonidae), minnows (family Cyprinidae), suckers (family Catostomidae), and sculpins (family Cottidae). Non-native species collected in the lower Snake River reservoirs consist of brown trout (*Salmo trutta),* catfish and bullhead (family Ictaluridae), sunfish, including smallmouth and largemouth bass, (family Centrarchidae), and perch (family Percidae).

Little difference occurs in species diversity among reservoirs (Bennett, 1991; PNL, 1995). Differences in relative abundance of each species which do exist are related to differences in habitat availability among reservoirs. Bennett et al. (1997b) and Dresser (1996) examined species associations with various habitat variables. They found substrate size, macrophyte biomass, and depth to be the predominant habitat variables characterizing use in Lower Granite Reservoir. Of particular significance to species diversity are the numbers of deeper areas with flowing water and shallow backwater and embayment areas.

GIS analysis (USGS; Cook, Washington, unpublished data) revealed that approximately 15.9 percent, or 2,058 ha (5,085 acres), of the area currently impounded by the four lower Snake River dams is shallow habitat (less than 5.5 m [18 feet]). Mid-depth (5.5 to 18.3 m [18 to 60 feet]) areas comprised 51.5 percent, or 6,655 ha (16, 445 acres); deep (greater than 18.3 m or 60 feet) areas comprised 31.9 percent, or 4,122 ha (10,186 acres); and islands comprised 90 ha (222 acres), or 0.7 percent of the total area. Differences between reservoirs were minor with the exception of Ice Harbor Reservoir. This reservoir has about the same amount of shallow water as the others, but has no deep water, and a large (64.7) percentage of water is between 9.1 and 18.3 m deep (30 and 60 feet) (Figure 5-12).

In general, shallow backwater and embayment areas of the lower Snake River reservoirs support a greater abundance of resident fish in all their early life stages than open-water areas. Backwater and embayment areas provide slightly warmer habitat, finer substrate, and submergent and emergent vegetation. Many resident species spend their entire life cycle in these shallow areas (Bennett et al., 1983).

Deep-water habitat supports fewer fish, the most common of which include suckers and minnows (PNL, 1995; Bennett et al., 1991; Bennett and Shrier, 1986). White sturgeon, a valued sport fish, also are often captured in deep pools (Bennett et al., 1991). Mid-depth areas of the reservoirs support a fish fauna intermediate to the shallow and deep areas.

By far, the majority of anglers using the lower Snake River reservoirs fishes for returning adult steelhead. U. of Idaho et al. (1998) estimated that 73 percent of all anglers May through November, 1997, for all four reservoirs, were seeking steelhead (Figure 5-13). However, an analysis of only resident species data (that is, excluding anglers seeking steelhead), showed 25.6 percent of all anglers on the lower Snake River reservoirs, May through November, 1997, sought channel catfish, 17.9 percent sought smallmouth bass, and 14.4 percent sought rainbow trout, the resident form of *O. mykiss* (Figure 5-14) (U. of Idaho et al., 1998).

5.2.1 Native Species

Cold-water resident species such as rainbow trout and mountain whitefish (*Prosopium williamsoni*), once common in the Snake and Columbia rivers, have declined since construction of the dams (Corps, 1992). Species composition has changed due to blockage of spawning migrations and modifications of habitats (Mullan et al., 1986). Currently, the dominant native species include northern pikeminnow, redside shiner (*Richardsonius balteatus*), mountain whitefish, chiselmouth (*Acrocheilus alutaceus*), bridgelip sucker (*Catostomus columbianus*), and largescale sucker (*C. macrocheilus*) (Bennett, 1991; Corps, 1992). In general, native species tend to be more prevalent in moving water areas of the reservoirs, for example, along the historic river channel or in the tailwater areas (Bennett et al., 1983; Bennett, 1991). Most native species spawn in flowing waters at the headwaters of the reservoirs or in tributary streams (Corps, 1992).

5.2.1.1 Family Acipenseridae (Sturgeon)

White Sturgeon

White sturgeon evolved in large, dynamic, free-flowing rivers and are found from the Gulf of Alaska south to the Sacramento-San Joaquin system. This species is thought to breed only in the Columbia, Rogue, and Sacramento-San Joaquin river systems. White sturgeon are exceptionally long-lived, and

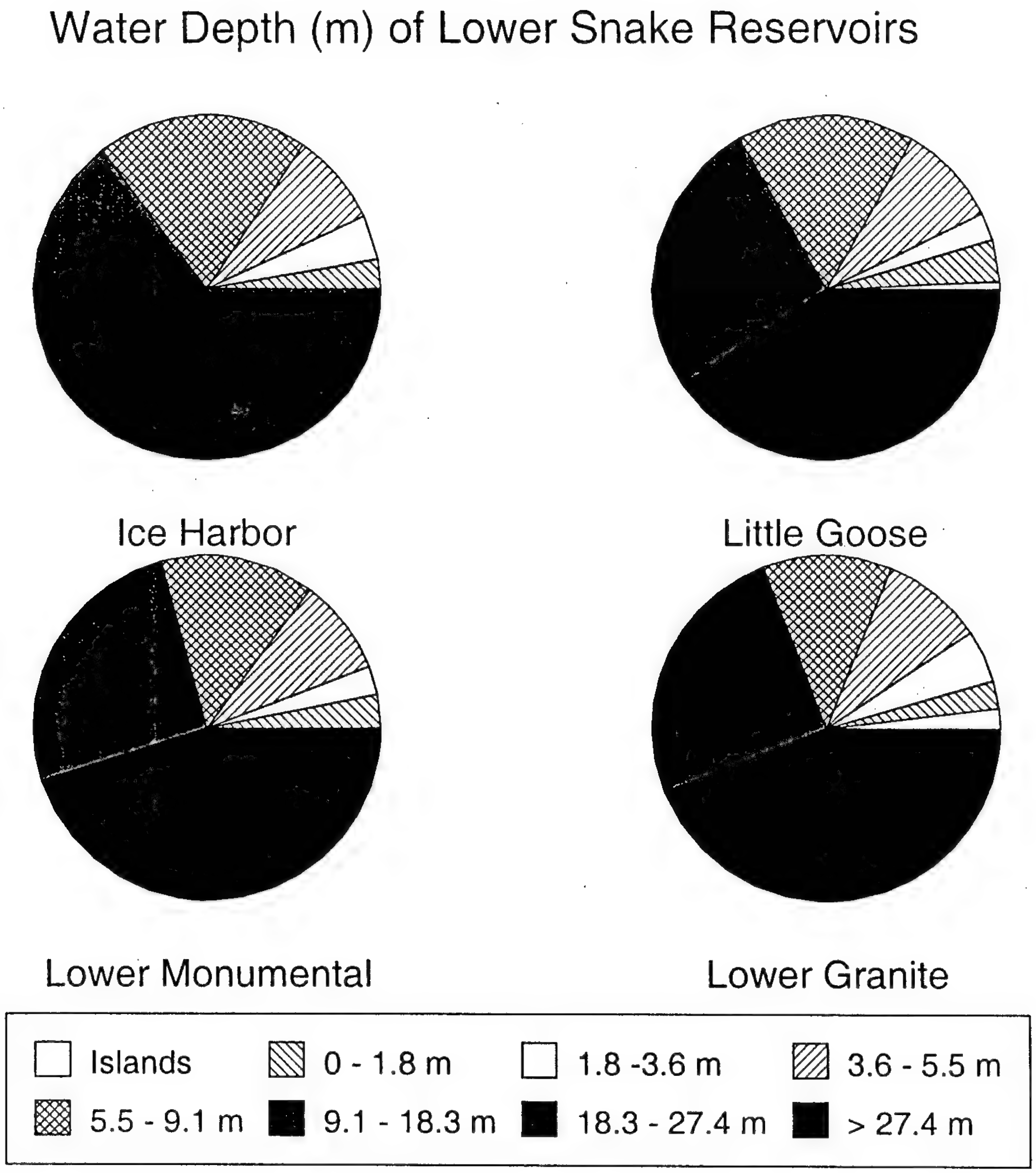

Figure 5-12. Relative Proportion of Areas of Given Water Depths for Each of the Lower Snake River Reservoirs

Source: USGS, unpublished data

Angler Preference
Lower Snake River Reservoirs
May through November, 1997

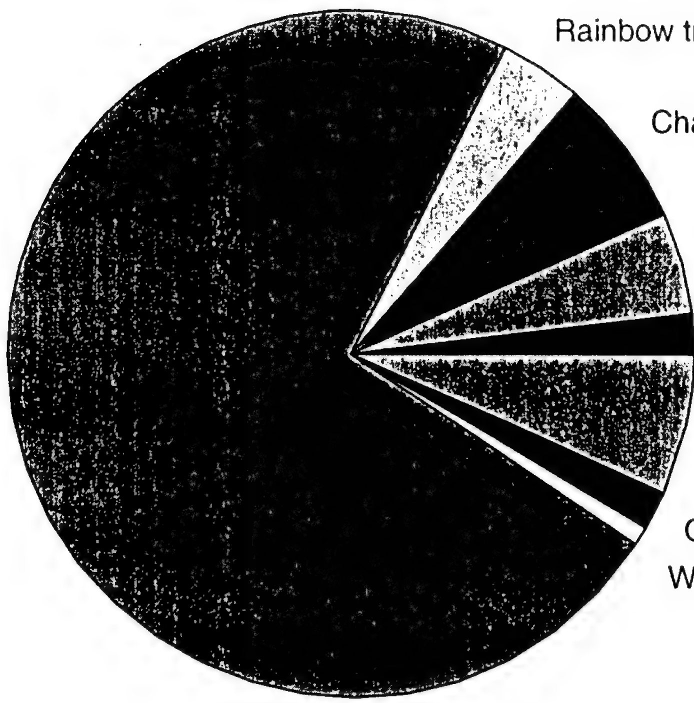

Figure 5-13. Relative Proportions of Interviewed Anglers Seeking a Particular Species for All Four Lower Snake River Reservoirs Combined.

Note: Number of anglers interviewed was 6,147 from May through November, 1997.
Source: U. of Idaho et al., 1998

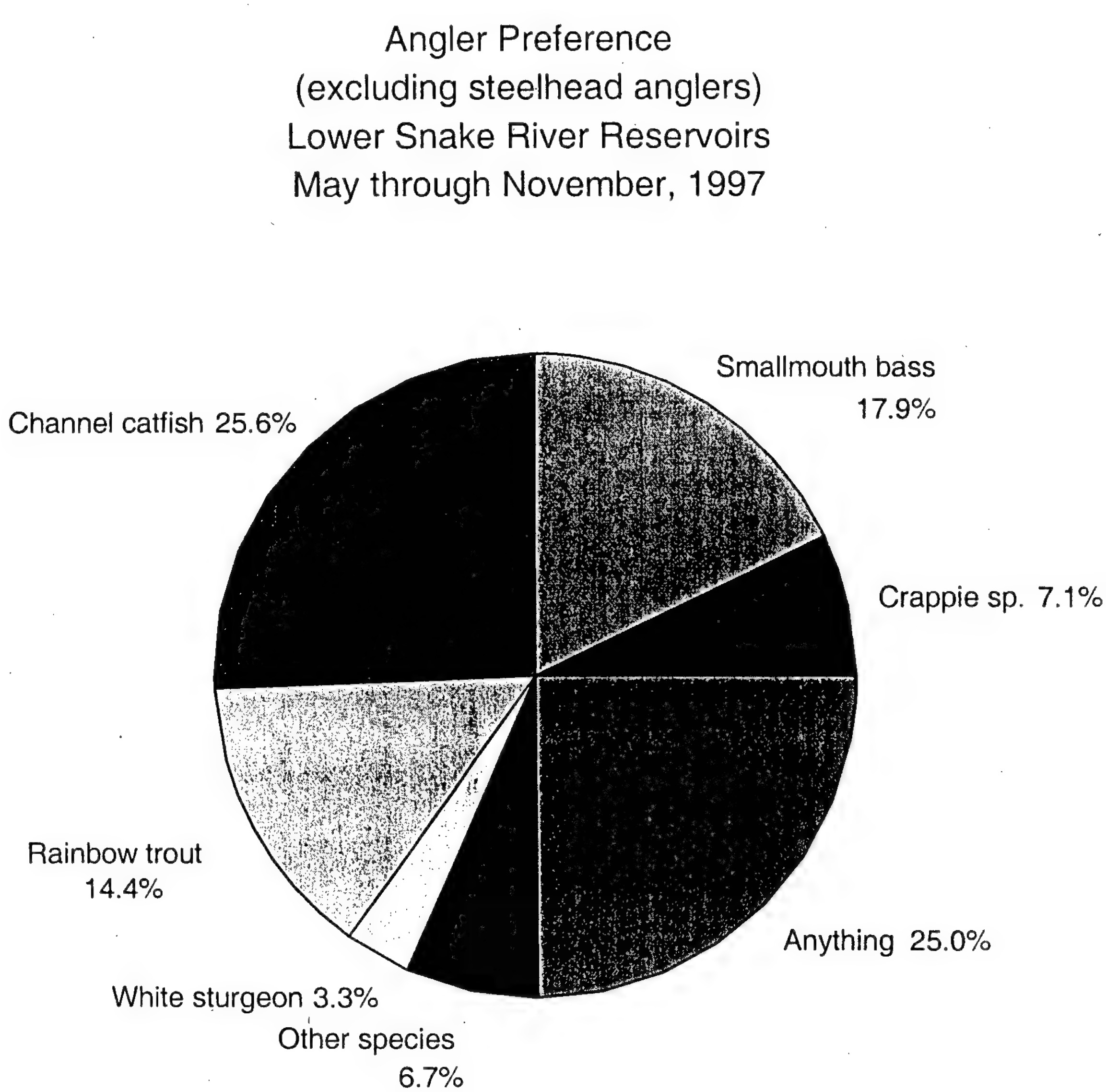

Figure 5-14. Relative Proportions of Interviewed Anglers, Excluding Steelhead Anglers, Seeking a Particular Species for All Four Lower Snake River Reservoirs Combined

Note: Number of anglers interviewed was 1,663 from May through November, 1997.
Source: U. of Idaho et al., 1998

individuals are known to have lived over 100 years. White sturgeon require different habitats throughout their long life, which they historically found through migration.

The free river access white sturgeon enjoyed between the Columbia and Snake rivers changed with the construction of dams. White sturgeon are still distributed throughout the river system, but they are now generally isolated, and their movement is limited within the series of impoundments that make up most of the river. White sturgeon very rarely use fish ladders. Use of the navigation locks to move between reservoirs is possible, but has not been documented (Parlsey 1998).

Although research has been limited, existing studies suggest that construction and operation of the hydropower system have severely impacted white sturgeon populations in the Columbia River Basin. Dams have blocked spawning and feeding migrations, effectively isolating sub-populations within reservoirs and eliminating their ability to migrate to the ocean to forage. They have impacted or destroyed much of the spawning habitat. White sturgeon juveniles and adults can be entrained and killed during dam maintenance activities (Parsley, 1998, citing John DeVore, personal communication). Dams and their associated reservoirs have also altered food availability, natural flow patterns, and water temperatures.

Because sturgeon are extremely vulnerable to modifications of their environment, the population status of white sturgeon stocks differs greatly among different reaches of the Columbia River and its tributaries. White sturgeon populations in the lower Columbia, for example, have been considered relatively healthy, whereas stocks in the Snake and Kootenai rivers have become severely reduced. Although it is clear that isolated white sturgeon populations can reproduce in some impoundments, how well they have adapted to environmental changes and what their long-range status are still unknown.

In the Columbia River System, white sturgeon spawn primarily during May and June. In their natural environment, spawning white sturgeon avoid slack water, preferring to deposit their eggs in rocky areas with fast-flowing water. In contrast to salmon and trout, white sturgeon require muddy, turbulent water for successful spawning. Mud or silt is critical in preventing the clumping and suffocation of eggs, and turbulence allows for proper aeration during development.

Spawning is initiated at water temperatures ranging from 10 to 12°C (50 to 54°F) and continues, in some instances, up to 20°C (68°F), although optimal spawning occurs at 14°C (57°F) (Parsley et al., 1993). It is important to note that developing white sturgeon embryos can experience elevated mortality beginning at water temperatures of 18°C (64°F), with complete mortality at 20°C (68F) (Wang et al., 1985).

Reproduction success varies in the reservoirs below Hells Canyon Dam and depends on temperature and flow conditions. Successful spawning has not been documented in the lower Snake River reservoirs, however, Parsley and Beckman (1994) have characterized suitable spawning habitat in the tailrace areas of dams in the lower Columbia River. It is possible that limited suitable spawning habitat occurs in the tailraces of the lower Snake River dams. Some unknown number of smaller juveniles are able to pass downriver through the dams providing some limited gene flow in one direction. Any individuals that do leave upriver populations do not return to them. Access to productive marine environments is no longer available for populations upriver of dams.

In the lower Snake River, white sturgeon tend to be more abundant in the more riverine areas, with faster water flow (Lepla 1994). In Lower Granite Reservoir, catch rates for white sturgeon were highest in the upstream end of the reservoir. Lepla (1994) found densities were highest in the upper

portion of the reservoir and decreased as he moved downstream. He estimated densities of 12 to 45 white sturgeon/rkm (19 to 72 white sturgeon per river mile) for Lower Granite Reservoir. Juveniles comprised a large portion (94 percent) of his sample. Coon et al. (1977) estimated 35 to 53 white sturgeon/rkm (56 to 85 white sturgeon per river mile) in the free-flowing stretch between Lower Granite Reservoir and Hells Canyon Dam.

Sturgeon showed a wide tolerance for habitat conditions (Lepla 1994). However, they preferred areas with higher velocity and larger substrate than were generally found downstream. Depths used by sturgeon ranged from 6.1 to 39.6 m (20 to 130 feet), with velocities ranging from 0.0 to 0.6 m/s (0.0 to 2.0 feet/s). Approximately 77 percent of the white sturgeon were captured in the thalweg.

5.2.1.2 Family Salmonidae (Salmon, Trout, Whitefish, and Charr)

Rainbow Trout

Rainbow trout do not spawn in lower Snake River reservoirs (PNL, 1995). Sexually mature adults normally seek cool water in tributaries, for example, the Tucannon or Clearwater rivers, to spawn during the spring. They require a gravel substrate to construct redds, and inter-gravel flow of cool, well-oxygenated water is necessary for successful incubation.

Rainbow trout are frequently caught in Lower Granite Reservoir (Bennett et al., 1988a), although most of these fish are probably juvenile steelhead released from upstream hatcheries that failed to successfully emigrate to the ocean; it is often difficult to distinguish between the two. Rainbow trout are caught infrequently in other lower Snake River reservoirs (Bennett et al., 1983). They persist largely by hatchery augmentation.

WDFW produces rainbow trout, as compensation for the lower Snake River facilities, at two facilities: the Tucannon Fish Hatchery and the Lyons Ferry Fish Hatchery (Herrig, 1990). Together, these two hatcheries rear approximately 86,000 pounds of rainbow trout annually. These fish are released into Idaho and Washington waters to compensate for recreational fishing opportunity lost by construction of the four lower Snake River dams. The releases provide a significant fishery in embayment areas adjacent to the reservoirs from March through May (U. of Idaho et al., 1998).

Kokanee

Kokanee (*Oncorhynchus nerka*), the resident form of sockeye salmon, have occasionally been collected in lower Snake River reservoirs (Bennett et al., 1983). Dauble and Geist (1992) collected juvenile kokanee in nearshore areas below Lower Granite Dam during the March 1992 drawdown test. Collection facilities at Lower Granite and Little Goose dams have also taken juvenile *O. nerka,* many of which were likely kokanee (PNL, 1995). Populations of kokanee exist upstream in the drainage in Dworshak Reservoir, on the Clearwater River, and in some lakes on the upper Salmon River (PNL, 1995). Kokanee found in the lower Snake River reservoirs are most likely members of these populations which have been displaced downstream.

Mountain Whitefish

Mountain whitefish have been collected in all four lower Snake River reservoirs, but are not currently abundant (Bennett et al., 1983; Bennett et al., 1997a; Bennett, 1991; Dresser, 1996). Mature adults

spawn in late fall to winter in moving water portions of the Snake and Clearwater rivers. They broadcast their eggs over gravel in stream riffles or shoals (Wydoski and Whitney, 1979).

Sexually mature mountain whitefish in the Lochsa River, a tributary to the Clearwater River, migrate to upper stream reaches in the spring (Berg and Rockhold, 1994). Towards late summer they begin migrating downstream out of the upper reaches to congregate in large, deep pools at lower elevations; nearby run/riffle habitat is used for spawning (Berg and Garcia, 1993). After spawning, mountain whitefish migrate lower in the system and overwinter in areas with less severe winter conditions. Pettit and Wallace (1975) found this same pattern in mountain whitefish in the North Fork Clearwater River. Fish were observed to migrate up to 88 km (55 miles) to reach areas for overwintering, then to return to the same small tributary in the headwaters area as the previous year (Pettit and Wallace, 1975; Berg and Rockhold, 1994).

Juveniles rear in Lower Granite Reservoir during spring and migrate upstream in the summer as water temperatures increase (Bennett, 1991). Adults may use reservoir areas for over-wintering.

5.2.1.3 Family Cyprinidae (Minnows)

Northern Pikeminnow

Northern pikeminnow are abundant in all four lower Snake River reservoirs (Bennett et al., 1983; Bennett, 1991; Bennett et al., 1991), but much less so than in the lower Columbia River (Parker et al., 1995; Ward et al., 1995). Chandler (1993) and Cichosz (1996) found northern pikeminnow densities in Lower Granite Reservoir of 1.2/ha (2.9/ac) to be notably lower than the 4.4/ha (10.9/ac) reported for John Day Reservoir; (Beamesderfer and Rieman, 1991). Although collected throughout the reservoirs, northern pikeminnow were generally collected in the upper 10 m (33 feet) of the water column (Bennett et al., 1983; Bennett et al., 1991). They tended to be more prevalent in moving water areas, especially in spring (Bennett et al., 1983; Shively et al., 1991), and within 20 m (66 feet) of the shoreline (USFWS, 1994).

Northern pikeminnow numbers may be declining. Data collected in 1993 showed fewer northern pikeminnow present, especially those more than 250 mm (9.8 inches) long, than in 1985 and 1987 (Bennett et al., 1997b). This may be partially due to the sport-reward program currently in place for northern pikeminnow (Bennett et al., 1997a; Cichosz, 1996). In an effort to increase exploitation of larger northern pikeminnow, and thereby decrease salmonid predation, anglers are paid $3.00 per northern pikeminnow more than 280 mm (11.0 inches) long throughout a major portion of the Columbia River Basin (Parker et al., 1995). From 1990 through 1993, approximately 600,000 northern pikeminnow were removed from the basin.

In reservoirs with major tributaries, northern pikeminnow are believed to migrate up tributaries in spring to spawn. For example, in Lower Granite Reservoir, northern pikeminnow migrate upstream to moving water areas of the Clearwater and Snake rivers (Bennett, 1991; Bennett et al., 1997a), and larval northern pikeminnow are collected in the greatest abundance from the upper reaches of the Lower Granite Reservoir (Cichosz, 1996). The Tucannon River, a tributary to Lower Monumental Reservoir, also is likely used for spawning. In reservoirs without major tributaries, for example, Ice Harbor and Little Goose reservoirs, northern pikeminnow probably migrate to tailwater areas for spawning (Bennett, 1991; Corps, 1992).

After hatching, young northern pikeminnow school in shallow areas (less than 1 m [3.3 feet] deep) with low velocity (less than 0.06 m/s [0.2 ft/s]) until the fall of their first year (Cichosz, 1996). This

appears to be the most critical stage for determining year class strength. Cichosz (1996) and Bennett et al. (1997a) found survival was not limited by density dependent factors, and early larval mortality is more important than spawning or hatching success in limiting abundance. Most mortality occurs before larvae obtain 18 mm (0.7 inches) in length (Bennett et al., 1997a). Northern pikeminnow larvae provide an important dietary item for fall chinook juveniles rearing in the reservoir (Curet, 1993), as well as for smallmouth bass and channel catfish (Anglea, 1997; Bennett et al., 1988b; Bennett et al., 1997a). However, predation is still a minor part of overall mortality (Bennett et al., 1997a; Cichosz, 1996).

Juvenile northern pikeminnow prefer shallow backwater areas with gentle, sloping shorelines, vegetation, and slight water velocity (Bennett, 1991). As the water cools, they move downstream or offshore to rear and overwinter in the reservoirs (Bennett et al., 1997a; Cichosz, 1996; Simpson and Wallace, 1982). In Lower Granite Reservoir, adult northern pikeminnow selected shallow (less than 6 m [20 feet]) deep), vegetated areas with small substrate (Bennett et al., 1997a). This is unlike habitat preferences observed by Dupont (1994) in northern Idaho's Pend Oreille River. Northern pikeminnow there selected deeper, rocky shorelines, with higher velocities. These differences could be related to the abundance of smallmouth bass and habitat partitioning in Lower Granite Reservoir (Bennett et al., 1997a). Population estimates of smallmouth bass in Lower Granite Reservoir were one and half to three times higher than those of northern pikeminnow (Bennett et al., 1997a).

Cichosz (1996) and Bennett et al. (1997a) found water flow, water temperatures, and water level fluctuations all to be significant variables when predicting northern pikeminnow survival. Northern pikeminnow abundance showed a positive correlation with water inflows. Also, the earlier that reservoir warming occurred, the higher the survival for both egg-to-larvae and juvenile stages (Cichosz, 1996). Earlier reservoir warming increases food production and availability, providing higher growth rates for the young northern pikeminnow and increasing survival.

Timing of surface water temperatures reaching 20°C (68°F) and greater had the opposite effect. The earlier surface water temperatures reached 20°C (68°F) and greater, the lower the northern pikeminnow survival (Cichosz, 1996). In Lower Granite Reservoir, surface water temperatures frequently exceed 20°C (68°F) from July through September. Although, adult northern pikeminnow prefer temperatures ranging from 16 to 22°C (61 to 72°F) (Brown and Moyle, 1981), temperatures greater than 20°C (68°F) probably inhibit growth and development of the young northern pikeminnow (Bennett et al., 1997a; Cichosz, 1996).

Water fluctuations can leave larvae and fry stranded out of water. Salmon management strategies such as flow augmentation with cooler water and maintenance of minimum operating pool water levels during spring and summer may enhance survival of larval northern pikeminnow, but reduce survival of juvenile northern pikeminnow (Cichosz, 1996).

Juvenile northern pikeminnow feed primarily on zooplankton, insects, and crayfish (Beamesderfer, 1983; Cichosz, 1996). Adult diets consist mainly of fish and crayfish (Chandler, 1993; Naughton, 1998); cladocerans, aquatic and terrestrial insects, and wheat have also been found in northern pikeminnow stomachs (Bennett et al., 1983; Bennett et al., 1988b; Bennett et al., 1991). Salmonids were the most important prey item by weight for adult northern pikeminnow during April, May, and June, the outmigration period for most salmonid smolts; whereas, crayfish and suckers were the most important prey items during the rest of the year (Chandler, 1993). Piscivory increases linearly with size; in Lower Granite Reservoir, northern pikeminnow less than 349 mm (13.7 inches) long are not

significant predators on salmonids which are outmigrating through the Snake River system (Chandler. 1993).

Northern pikeminnow have also been documented to hybridize with chiselmouth in the lower Snake River reservoirs (Naughton, 1998). F_1 hybrids apparently are just as piscivorous as northern pikeminnow, although they may have to reach a slightly larger size (greater than 280 mm or 11 inches) before becoming effective predators (Smith, 1996). In 1995, 251 northern pikeminnow x chiselmouth hybrids were reported to the sport reward program's Greenbelt registration station; only 39 were reported to the other 12 registration stations. Reasons for this hybridization and difference in distribution are not known.

5.2.1.4 Redside Shiner

Redside shiners are abundant in all four lower Snake River reservoirs (Bennett, 1991; Bennett et al., 1988b, Bennett et al., 1983; Bennett and Shrier, 1986; Chandler, 1993), although fewer are found in Lower Granite Reservoir than in other reservoirs (Bennett, 1991). Abundance of redside shiners decreased in Lower Granite Reservoir from 1985 and 1987 to 1993 (Bennett et al., 1997a).

Redside shiners generally spawn in the spring and early summer (Simpson and Wallace, 1982; Wydoski and Whitney, 1979). However, spawning may occur as late as August in lower Snake River reservoirs (Bennett et al., 1983). Adults move to nearshore areas as shallow as 15 cm (6 inches) or less in spring when water temperatures warm to 10°C (50°F) (Simpson and Wallace, 1982; Wydoski and Whitney, 1979). Spawning occurs in small groups of 20 to 30 individuals (Simpson and Wallace, 1982), and adhesive eggs are broadcast over the gravel bottom of streams or in vegetation along lake shorelines (Wydoski and Whitney, 1979). Immediately after hatching, fry migrate to pools or areas with no perceptible current (Simpson and Wallace, 1982). Hjort et al. (1981) found redside shiners primarily in pools and side channels of the Umatilla River, upstream of the area influenced by John Day Dam, in 15 to 60 cm (6 to 24 inches) of water, over rock or gravel substrate, often with dense mats of algae present.

In the lower Snake River, redside shiners were commonly collected in moving water areas and showed a positive correlation with velocity and inflow levels (Bennett et al., 1983; Bennett et al., 1997a). Although most commonly collected in the upper 10 m (33 feet) of the water column (Bennett et al., 1983; Bennett et al., 1988b), they were also one of the dominant species collected at deep sites (Bennett et al. 1988b). Chandler (1993) found a high abundance of young-of-the-year redside shiners in littoral areas of Lower Granite Reservoir.

Redside shiners prey on small planktonic organisms, but switch to aquatic and terrestrial insects, zooplankton, and snails by the second year of life (Simpson and Wallace, 1982; Wydoski and Whitney, 1979). In the lower Snake River reservoirs, redside shiners prey mainly on cladocerans and aquatic and terrestrial insects (Bennett et al., 1983).

Chiselmouth

Chiselmouth are abundant throughout all four lower Snake River reservoirs (Bennett et al., 1983; Bennett, 1991; Bennett and Shrier, 1986; Bennett et al., 1991; Bennett et al., 1988a; Bennett et al., 1988b; Bennett et al., 1997a; Dresser, 1996; Shively et al., 1991). Typically young chiselmouth select sites with small substrate and vegetation, probably for rearing and feeding on insects (Bennett et al., 1997b), and are abundant in shallow areas (Bennett et al., 1988a; Bennett et al., 1991). Young chiselmouth contribute significantly to the diet of smallmouth bass, and likely, to that of other

piscivorous fish in the lower Snake River reservoirs (Bennett et al., 1988b). This species may serve as a major link in the food chain, from primary production to piscivorous fish (Wydoski and Whitney, 1970).

Dresser (1996) found chiselmouth move offshore during fall. Adults are found primarily in the upper 10 m (33 feet) of the water column throughout the reservoir (Bennett et al., 1983) and are more prevalent in areas with moving water conditions (Bennett et al., 1983; Bennett, 1991). They select areas with increased velocity (Bennett et al., 1983). Bennett et al. (1997b) suggest the chiselmouth population in Lower Granite Reservoir is currently below carrying capacity. In the mid-Columbia River, populations of chiselmouth increased after impoundment, most likely due to a lack of competition for their increased primary food source, periphyton (Mullan et al., 1986).

Although also abundant in the Columbia and Yakima rivers, very little information is available on the spawning habits or life history of chiselmouth (Simpson and Wallace, 1982, Wydoski and Whitney, 1979). Apparently they spawn in late spring and early summer when water temperatures exceed 15°C (59°F) (Simpson and Wallace, 1982, Wydoski and Whitney, 1970). Spawning occurs in streams over gravel or rubble substrate, with no evidence of nest building documented (Simpson and Wallace, 1982). Young fish are surface feeders and consume insects and plankton. Adults feed exclusively on various forms of algae attached to rocks and other substrate.

As noted above, chiselmouth have been known to hybridize with northern pikeminnow. Although adult chiselmouth are herbivores, the resultant F_1 hybrids can be quite piscivorous once a fork length of approximately 180 mm (7.1 inches) or greater is attained (Smith, 1996).

Peamouth

Adult peamouth (*Mylocheilus caurinus*) spawn in lower Snake River reservoirs during spring and summer when temperatures reach approximately 12°C (54°F) (Bennett et al., 1983; Simpson and Wallace, 1982; Wydoski and Whitney, 1979). They are broadcast spawners, choosing a gravel or rubble substrate in very shallow water in either streams or lakes (Simpson and Wallace, 1982; Wydoski and Whitney, 1979). Eggs adhere to the substrate until hatching. Young peamouth remain in shallow water until their first winter (Wydoski and Whitney, 1979), feeding on crustaceans and aquatic insects (Simpson and Wallace, 1982). Adults move offshore during daylight hours and into the shallows at night (Wydoski and Whitney, 1979). They tend to feed on aquatic insects, taking terrestrial insects when available (Simpson and Wallace, 1982).

Although larval peamouth are often locally abundant, especially in shallow rearing areas, (Bennett and Shrier, 1986; Chandler, 1993), peamouth are generally uncommon in all four lower Snake River reservoirs (Bennett et al., 1983; Bennett, 1991). They are less commonly observed than suckers, carp, or chiselmouth (Shively et al., 1991). Mullan et al. (1986) reported numbers of peamouth present in the mid-Columbia River declined after dam construction and river impoundment.

Young peamouth inhabit very shallow water in spring, summer, and fall. In British Columbia, adults remain on the bottom in deep water during the day and move into the shallow areas at night. When in water less than 20 m (66 feet) deep, they remain near the bottom (Wydoski and Whitney, 1979). Spawning begins late in May, but occurs primarily in June in John Day Reservoir, when temperatures reach about 12°C (54°F). Peamouth were caught in all habitats with the highest catches occurring in the tailrace area over all types of substrate with and without vegetation (Hjort et al., 1981).

5.2.1.5 Family Catostomidae (Suckers)

Two species of suckers are abundant in the lower Snake River reservoirs, the largescale and the bridgelip sucker (Bennett, 1991; Bennett et al., 1997a; Bennett et al., 1997b; Bennett et al., 1991; Bennett et al., 1983; Dresser, 1996). They are among the dominant species in riverine habitats such as the old river channel and tailwater areas of the dams (Bennett et al., 1983; USFWS 1993a; Larson and Grettenberger, 1991). Suckers spawn in the moving water areas of the Clearwater, Snake, and probably Palouse rivers (Bennett, 1991). In reservoirs without major tributaries, the tailwater area of the upstream dam can also function as a spawning area (Bennett, 1991). Suckers are known to spawn in Lower Granite, Little Goose, and Lower Monumental reservoirs. Recently hatched fry are pelagic (Wydoski and Whitney, 1979) and rear in the reservoirs (Bennett et al., 1991).

Juvenile and larvae suckers provide an important prey base for piscivorous fish in the lower Snake River (Chandler, 1993). Catostomids dominated the non-salmonid component of the northern pikeminnow diet during all years sampled (1987 through 1991) (Chandler, 1993).

Largescale Sucker

Largescale suckers are abundant throughout all four lower Snake River reservoirs (Bennett, 1991; Bennett et al., 1997a; Bennett et al., 1997b; Bennett et al., 1991; Bennett et al., 1983; Dresser, 1996). In Lower Granite Reservoir, largescale suckers clearly dominated the overall fish biomass at all sites sampled, including the deep water (greater than 18 m [59 feet] deep) sites (Bennett et al., 1997b; Bennett et al., 1988a; Bennett et al., 1988b).

Largescale suckers spawn when water temperatures reach 8 to 9°C (47 to 48°F) (Simpson and Wallace, 1982). In lower Snake River reservoirs, spawning occurred in May and June (Bennett et al., 1983). Eggs are adhesive and are broadcast over areas of sand or small gravel (Simpson and Wallace, 1982; Wydoski and Whitney, 1979).

Largescale suckers showed little habitat preference and a wide distribution in varied habitats (Bennett et al., 1997b; Bennett et al., 1991; Bennett et al., 1983; Dresser, 1996; Dupont, 1994). Although largescale suckers dominated the nearshore catches during daylight hours, they have also been captured at depths up to 6 m (20 feet) in the Hanford Reach of the Columbia River (Dauble, 1978).

The diet of this fish consists largely of plant material (diatoms, detritus, and bluegreen and filamentous algae; Bennett et al., 1983); midges, and other aquatic invertebrates have also reportedly been consumed by this species (MacPhee and Brusven, 1974; Simpson and Wallace, 1982).

Bridgelip Sucker

Bridgelip suckers were abundant in the Ice Harbor, Lower Monumental, and Little Goose reservoirs and common in Lower Granite Reservoir (Bennett, 1991). They were about one third as abundant in Lower Granite Reservoir as were largescale suckers (9.7 percent of the over all catch versus 28 percent) (Bennett et al., 1997b).

Although bridgelip and largescale suckers have been frequently captured together (Dauble, 1978), it appears they have somewhat different habitat preferences (Bennett et al., 1997b). Bridgelip suckers tend to prefer deeper water, larger substrate (greater than 50 mm or 2.0 inches), and greater slopes than do largescale suckers (Bennett et al., 1997b; Dauble, 1978; Dresser, 1996).

Dauble (1978) commonly observed largescale suckers in slack waters less than 1 m (3.3 feet) deep; bridgelip suckers were never similarly observed. Both species inhabited nearshore areas in similar proportions during the night, but bridgelip suckers moved offshore to depths greater than 2 m (6.6 feet) during daylight hours (Dauble, 1978). Bridgelip suckers can also tolerate higher velocities, but a narrower range of water temperatures, than largescale suckers.

The dominant food item for all sizes of bridgelip suckers was periphyton (Bennett et al., 1983; Dauble, 1978). Other important prey items included midges, zooplankton, and miscellaneous aquatic invertebrates.

Nearshore areas of the tailrace and transition zones provided important rearing areas for native minnows and suckers in John Day Reservoir. The open area of the tailrace was the main spawning area for these fish. However, bridgelip suckers may also have spawned in tributaries away from the influence of the main reservoir (Hjort et al., 1981). Bridgelip suckers were most common in open areas of the reservoir, especially in the tailrace zone. They were positively correlated with current and with selected areas of Lower Granite Reservoir having substrate greater than 50 mm (2 inches) in diameter and increased slope and depth (Bennett et al., 1997). Sub-adult and adult bridgelip suckers were common during daylight in tailouts of pools 1 to 2 m (3.3 to 6.6 feet) and deeper, at the end of riffles, and above boulders in the main current (Dauble, 1980). Although caught in deep waters, catch rates were highest near the shore (Hjort et al., 1981).

5.2.1.6 Other Species (Sand Roller, Sculpins)

Family Percopsidae (Trout Perch), Sand Roller

Sand rollers (*Percopsis transmontana*) are most abundant in the lower Columbia River, but they have been collected as far upstream as the Clearwater River (Gray and Dauble, 1979). Sand rollers move into shallow areas with sandy or gravel substrate to spawn (Simpson and Wallace, 1982) during mid-summer when water temperatures are 14 to 16°C (57 to 61°F) (Gray and Dauble, 1979). Food consists of small invertebrates, especially midges, caddis flies, and scuds (Gray and Dauble, 1976; Simpson and Wallace, 1982). A few sand rollers have appeared in the stomachs of smallmouth bass collected from lower Snake River reservoirs (D.H. Bennett, U. of Idaho, professor of fisheries, personal communication).

In the Hanford Reach of the Columbia River, sand rollers were collected over rock or sand bottoms (Gray and Dauble, 1976; Gray and Dauble, 1979). Most fish were collected in 1 to 2 m (3.3 to 6.6 feet) of water; however, they have been observed holding in shallow depressions at water depths to 4 m (13.1 feet). Sand rollers are a territorial species (Wydoski and Whitney, 1979) and were observed spaced about 1 m (3.3 feet) apart when no cover was available (Gray and Dauble, 1976).

Family Cottidae (Sculpin)

Three species of sculpins have been collected in the lower Snake River reservoirs: prickly, Piute, and mottled sculpins (*Cottus asper, C. beldingi,* and *C. bairdi*, respectively) (Bennett et al., 1983). Bennett (1991) reports sculpins to be uncommon in Lower Granite Reservoir, common in Little Goose Reservoir, and of unknown status in Lower Monumental and Ice Harbor reservoirs. Shively et al. (1991) also rarely saw sculpins in the lower Snake River reservoirs. Prickly sculpins are abundant in the Columbia River reservoirs (Page et al., 1982).

Sculpins showed a preference for habitat with higher water velocity, colder water temperatures, and larger substrate than what was generally available in Lower Granite Reservoir (Bennett et al., 1997b; Dresser, 1996). Prickly sculpins spawn in both open water and backwater areas (Hjort et al., 1981).

White sturgeon, northern pikeminnow, and smallmouth bass all prey on sculpins, especially in the absence of salmonid smolts (MacPhee and Brusven, 1974; Poe et al., 1991; Ringe and Coon, 1974).

5.2.2 Non-native Species

Of the 18 non-native species collected in lower Snake River reservoirs, the most common are carp, channel catfish, pumpkinseed (*Lepomis gibbosus*), and smallmouth bass (Bennett, 1991). White crappie, black crappie, and yellow perch are also abundant, but only in localized areas.

5.2.2.1 Family Cyprinidae (Minnow)

Carp

Carp are the only non-native cyprinid abundant in the lower Snake River reservoirs (Bennett et al., 1983; Bennett et al., 1988b; Bennett, 1991; Shively et al., 1991). Carp prefer warm, moderately shallow water with aquatic vegetation (Simpson and Wallace, 1982). They tend to avoid clear, cold water and are tolerant of water with high turbidity and low dissolved oxygen (Simpson and Wallace, 1982; Wydoski and Whitney, 1979). They are a highly prolific, spring-spawning species that broadcast their adhesive eggs in very shallow water when temperatures reach approximately 15°C (59°F) (Wydoski and Whitney, 1979). Carp are omnivores and will eat almost all available forms of organisms of suitable size (Simpson and Wallace, 1982); however, vegetation makes up the bulk of their diet.

Carp are abundant in all four lower Snake reservoirs; however, they appear in greater abundance in the lower two reservoirs (Bennett et al., 1983; Bennett, 1991). Although widely distributed throughout the reservoirs, carp were found to be negatively correlated with depth and water clarity (Bennett et al., 1983). They inhabit waters with little current velocity, often with soft substrate and emergent and submergent vegetation present (Bennett, 1991). They tend to be captured during bottom or mid-depth sampling, rather than surface sampling (Bennett et al., 1988b). In Lower Granite Reservoir, most fish larvae captured in embayments were carp (Bennett et al., 1997b).

5.2.2.2 Family Ictaluridae (Catfish)

Several members of the catfish family have been introduced to the Snake River. These include channel and flathead catfish (*Pylodictis olivaris*); brown, black, and yellow bullheads (*Ictalurus nebulosus*, *I. melas*, and *I. natalis*, respectively); and the tadpole madtom (*Noturus gyrinus*) (Bennett et al., 1983; Bennett, 1991; Corps and NMFS, 1994). Of these, channel catfish is the only species common in the Snake River reservoirs (Bennett, 1991).

Channel Catfish

Channel catfish are among the most sought after resident sport fish in the lower Snake River reservoirs (USFWS, 1993a, USFWS, 1994) and the most sought after species in Little Goose and Lower Monumental reservoirs (U. of Idaho et al., 1998). Although they can tolerate a wide range of conditions, they are most often found in clear lakes, reservoirs, and streams (Wydoski and Wallace, 1979). This species spawns in the summer when water temperature reaches 21°C (70°F) or higher.

seeking dark, secluded areas such as undercut banks, large rocks, or hollow logs for nest building (Simpson and Wallace, 1982; Wydoski and Whitney, 1979). Bennett et al. (1983) documented spawning in Little Goose Reservoir in July and August. After spawning, the female leaves the area, and the male guards and fans the eggs until they hatch and the young leave the nest (Simpson and Wallace, 1982). The popularity of the channel catfish as a sport fish has increased in recent years.

Channel catfish are common throughout all four reservoirs (Bennett et al., 1983; Bennett, 1991; Bennett et al., 1991). They were found to be more abundant in Ice Harbor and Lower Monumental reservoirs than in Little Goose and Lower Granite reservoirs (Bennett et al., 1983; Bennett, 1991). Channel catfish preferred tailwater areas during spring, but dispersed throughout the reservoirs during the summer and fall (Bennett et al., 1983; Bennett et al., 1991). They tend to be captured in the lowest 10 m (33 feet) of the water column (Bennett et al., 1983). Over the last few years, the number of large channel catfish present in Lower Granite Reservoir has remained relatively constant; however numbers of younger channel catfish appear to be increasing (Bennett et al., 1997a).

Channel catfish prey consisted of fish, aquatic insects, crayfish, wheat, and cladocerans (Bennett et al., 1983). Although, predation was curtailed at water temperatures lower than 10°C (50°F), steelhead smolts still contributed substantially to the channel catfish diet during spring months (Bennett et al., 1983; Bennett and Shrier, 1986; Bennett et al., 1988b; Bennett, 1991). After the main outmigration of smolts passes, crayfish become an extremely important component of the channel catfish diet (Bennett et al., 1983; Bennett et al., 1988b; Bennett and Shrier, 1986).

Bullheads (Yellow, Black, and Brown)

Although not common throughout the reservoirs, bullheads are sometimes locally abundant in embayment and backwater areas (Bennett, 1991; Bennett et al., 1997a; Bennett et al., 1983). Yellow, black, and more commonly, brown bullhead have all been captured in the lower Snake River reservoirs (Bennett et al., 1997a; Bennett et al., 1991; Bennett et al., 1983). Unlike channel catfish, bullhead prefer vegetated areas in ponds, sloughs, and lakes (Simpson and Wallace, 1982; Wydoski and Whitney, 1979).

Bennett et al. (1983) found brown bullhead spawned in June, July, and early August. Yellow bullhead were positively correlated with depth, while brown bullhead were negatively correlated with both depth and velocity. In general, bullheads provide little recreational value in the lower Snake River (USFWS, 1993a; USFWS, 1994).

5.2.2.3 Family Centrarchidae (Sunfish)

Largemouth Bass

Largemouth bass presence and abundance in Snake River reservoirs is closely linked with backwater and embayment areas in all four lower Snake River reservoirs (Bennett, 1991; Bennett, et al. 1983). Backwaters and embayments generally provide slightly warmer habitat, finer substrate, and more submergent and emergent vegetation than other areas of the reservoirs (Bennett, 1991). Largemouth bass are abundant in backwater areas of all four lower Snake River reservoirs, but are more abundant in Lower Monumental Reservoir than in Lower Granite Reservoir, presumably due to a higher abundance of preferred habitat.

Largemouth bass are tolerant of warm water and prefer clear, shallow (less than 6 m [20 feet] deep), weedy areas of lakes, reservoirs, and rivers (Wydoski and Whitney, 1979). They are usually found in association with structures to provide cover. Optimal water temperature for growth appears to be around 26°C (79°F) and the fish become inactive below 10°C (50°F) (Wydoski and Whitney, 1979). Largemouth bass spawn when water temperatures reach 15°C (59°F) to 18°C (64°F) in depths up to 2.5 m (8.2 feet).

During the 1992 experimental drawdown of Little Goose and Lower Granite reservoirs, largemouth bass were among those fish found stranded and were, possibly, the species most seriously impacted by the drawdown (Schuck, 1992). More adult largemouth bass were found stranded than any other species. Populations of largemouth bass were not large to begin with, and preferred habitat for largemouth bass in these reservoirs is limited.

Smallmouth Bass

Smallmouth bass, a popular sport fish, were introduced to the Snake River in the 1800s (Munther, 1970). They provide a much better fight than the largemouth bass, and the firm, white, flaky, and very tasty flesh make them a favorite among anglers (Simpson and Wallace, 1982, Wydoski and Whitney, 1979). In the lower Snake River reservoirs, they are the second most sought-after resident game fish. Excluding steelhead angler data, 17.9 percent of all anglers on the lower Snake River reservoirs preferred to catch smallmouth bass, May through November, 1997 (Figure 5-14) (U. of Idaho et al., 1998).

Smallmouth bass prefer the cool water of streams with extensive riffle areas and clean gravel or rubble bottoms or lakes with rock ledges or outcroppings (Simpson and Wallace, 1982). Spawning occurs in spring when water temperatures reach 13 to 18°C (55 to 64°F) (Wydoski and Whitney, 1979). Adults commonly enter embayments or other areas warmed by insolation to spawn (PNL, 1995). Males build a shallow nest on the sandy gravel or rocky bottoms of streams or lakes and guard the nest after the female lays the eggs (Simpson and Wallace, 1982; Wydoski and Whitney, 1979). Males continue to guard the young until the fry have dispersed (Simpson and Wallace, 1982). Typically, predation is high on the young, and survival to adulthood is relatively low.

Smallmouth bass are well established throughout the Snake River Basin (Anglea, 1997; Bennett, 1991; Bennett et al., 1983; Munther, 1970; Shively et al., 1991). They were the most abundant resident game species in samples from the lower Snake River reservoirs and made up 14 percent of the total catch (Bennett, 1991; Bennett et al., 1983). Fewer smallmouth bass were sampled in winter and spring than in summer and fall months (Bennett et al., 1991; Bennett et al., 1988b), probably due to limited movement of smallmouth bass during colder temperatures.

Numbers of smallmouth bass in Lower Granite Reservoir increased from 1987 to 1993 (Bennett et al., 1997b). Size distribution, however, did not change over the same period. Anglea (1997) estimated 21,000 adult smallmouth bass bigger than 175 mm (6.9 inches) were present in Lower Granite Reservoir. As in previous work, he found smallmouth bass distributed throughout the reservoir.

In the lower Snake River reservoirs, smallmouth bass spawning occurs during late May, June, and July (Bennett et al., 1983). Water fluctuations associated with power operation can fatally expose smallmouth bass nests. Young-of-the-year and yearling smallmouth bass have been collected abundantly at shallow stations (Bennett et al., 1988a).

Unlike most resident game species, smallmouth bass were collected throughout the reservoirs and exhibited wide habitat use (Bennett et al., 1983; Bennett and Shrier, 1986; Dresser, 1996). They were captured more frequently in shallow areas and in areas with substrate larger than 250 mm (9.8 inches). They tend to be absent from areas with substrate composed of silt and sand (Bennett et al., 1997b; Dresser, 1996). Smallmouth bass were more abundant in upstream reservoirs than in Ice Harbor Reservoir, possibly because of greater sedimentation in the older reservoir behind Ice Harbor Dam (Bennett, 1991; Bennett et al., 1983).

Major food items include crayfish, fish, and terrestrial and aquatic insects (Bennett et al., 1997b; Bennett et al., 1983). Smallmouth bass fed heavily on fish April through July, but as salmonid outmigration ceased, smallmouth bass fed more heavily on resident fish, such as northern pikeminnow, suckers, and crayfish (Bennett et al., 1997b). Smallmouth bass are opportunistic feeders, able to quickly capitalize on whatever prey base is abundant (Bennett et al., 1997b; Keating, 1970). They have been documented to prey on salmonid smolts (Anglea, 1997; Bennett et al., 1988a; Bennett et al., 1988b; Bennett and Shrier, 1986).

Crayfish become the dominant prey item for most smallmouth bass when smolts are not abundant (Bennett et al., 1997b; Bennett and Shrier, 1986; Shively et al., 1991). Bennett et al. (1983) found crayfish to be the most important prey item for smallmouth bass regardless of season or habitat and suggested this is due to the abundance of crayfish in the Snake River.

Although probably the most abundant predator on outmigrating smolts in the lower Snake River reservoirs, overall smolt consumption was low (Bennett et al., 1988a; Bennett et al., 1988b; Bennett et al., 1983; Shively et al., 1991). Water temperatures are often lower than 10°C (50°F) during the major smolt outmigration; temperatures this low curtail active foraging by smallmouth bass, as well as channel catfish, and white crappie (Bennett et al., 1997b; Bennett, 1991).

Lepomis sp. (Bluegill, Green Sunfish, Pumpkinseed, and Warmouth)

These sunfish are considered to be very edible and, although they tend to be small, are sometimes considered a valuable panfish. They contribute, in a minor way, to recreational sport fishing in lower Snake River reservoirs (USFWS, 1993a). In 1997, these species comprised 5.5 percent of the total resident fish catch in the lower Snake River reservoirs (Figure 5-15) (U. of Idaho et al., 1998).

Bluegill, green sunfish (*Lepomis cyanellus*), pumpkinseed, and warmouth are all nest builders. Males build nests in shallow water, then guard them until fry disperse. Sunfish generally eat snails and insects (Simpson and Wallace, 1982). Bluegill and pumpkinseed occur abundantly in backwater and embayment areas of all four lower Snake River reservoirs (Bennett, 1991). These areas generally provide slightly warmer habitat, finer substrate, and emergent and submergent vegetation (Bennett, 1991). In Little Goose Reservoir, bluegill spawned during July and early August; pumpkinseed spawned from late June through early August (Bennett et al., 1983).

Bennett (1991) reports warmouth do not occur in Lower Granite Reservoir, but occasionally have been captured in Little Goose Reservoir. Their status is unknown in Ice Harbor and Lower Monumental reservoirs (Bennett, 1991). Green sunfish have been caught in Lower Granite Reservoir, but only very rarely (T. J. Dresser, USFWS, fisheries biologist, personal communication).

Angler Catch (Excluding Steelhead)
Lower Snake River Reservoirs
April through November, 1997

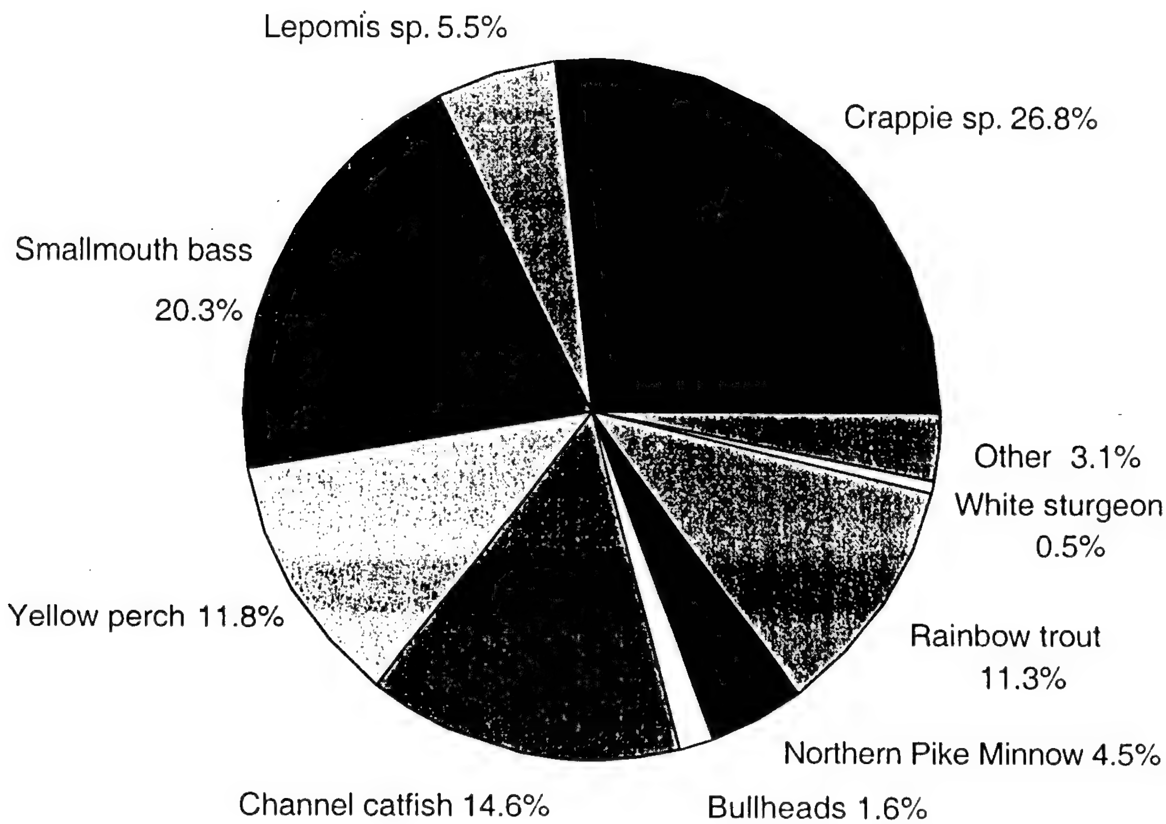

Figure 5-15. Composition (Percent) of Angler Catch (Excluding Steelhead) from All Four Lower Snake River Reservoirs Combined, April through November, 1997

Note: Crappie sp. include Black and White; Lepomis sp. include Bluegill and Pumpkinseed; other may include Carp, Suckers, Peamouth, and Chiselmouth (U. of Idaho et al., 1998).

Pomoxis sp. (Black Crappie, White Crappie)

Both black and white crappies are locally abundant in all four lower Snake Reservoirs (Bennett. 1991). White crappies, along with smallmouth bass, channel catfish, and yellow perch, are among the most frequently caught resident sport fish in the lower Snake River reservoirs (USFWS, 1993a; U. of Idaho et al., 1998). Black crappie also provide recreational fishing, to a lesser degree, in the lower Snake River reservoirs (USFWS, 1993a; USFWS, 1994). Together, these species comprised 26.8 percent of the total resident fish catch in the four lower Snake River reservoirs (Figure 5-15) (U. of Idaho et al., 1998). Both species are considered an excellent panfish (Wydoski and Whitney, 1979).

Like other sunfish, crappies are nest-builders; males build and guard the nests until fry disperse (Simpson and Wallace, 1982). Crappies select spawning areas with little or no current velocity (Bennett, 1991). White crappie spawn at a slightly warmer temperature, 18 to 20°C (64°F to 68°F), than do black crappie, 14 to 18°C (57 to 64°F) (Wydoski and Whitney, 1979).

Crappies are found primarily in backwater and embayment areas (Bennett et al., 1983). They prefer vegetated areas with shallow depths, small substrate, and low current velocity (Bennett et al., 1997a; Dupont, 1994). White crappie have also been collected in mid-depth and deep areas of the Lower Granite Reservoir (Bennett et al., 1991).

Both species are considered locally abundant in backwater and embayment areas of all four reservoirs (Bennett, 1991; Bennett et al., 1983). Crappies are less abundant in Lower Granite Reservoir than Little Goose and possibly Lower Monumental and Ice Harbor reservoirs (Bennett, 1991). However, their numbers in Lower Granite Reservoir have increased from 1987 to 1993 (Bennett et al., 1997a). White crappies tend to be more abundant in lower Snake River reservoirs than black crappies (Bennett et al., 1997b, Bennett et al., 1983).

The diet of crappies consists mainly of crayfish, molluscs, aquatic insects, and cladocerans (Bennett et al., 1997b; Bennett et al., 1983). Although white crappies have been documented to prey on salmonid smolts, smolts do not constitute a major item in their diet (Bennett and Shrier, 1986; Bennett et al., 1997b).

5.2.2.4 Family Percidae (Perch)

Yellow Perch

Yellow perch are not considered abundant throughout any of the lower Snake River reservoirs, but are often locally abundant (Bennett, 1991; Bennett and Shrier, 1986; Bennett et al., 1997a; Bennett et al., 1997b; Dresser, 1996; Larson and Grettenberger, 1991). Yellow perch were negatively correlated with depth and strongly correlated with aquatic vegetation and preferred littoral habitat (Bennett et al., 1997b; Bennett et al., 1983; Dresser, 1996). In Lower Granite Reservoir, yellow perch have been collected at both shallow and mid-depth sites (up to 18 m [59 feet]); Bennett et al., 1991), but abundance has remained low since 1986 (Dresser, 1996).

Yellow perch spawn during spring when water temperatures reach 5.5 to 11.0°C (42 to 52°F) (Wydoski and Whitney, 1979). Females release their eggs over various types of bottom (sand, gravel, or rubble) and on vegetation or submerged brush and other objects (Simpson and Wallace, 1982; Wydoski and Whitney, 1979). Eggs are extruded in a flat, ribbon-like, gelatinous, semi-buoyant mass (Simpson and Wallace, 1982; Wydoski and Whitney, 1979). Young rear near shore until late in their first fall, when they move into deeper waters (Wydoski and Whitney, 1979). Adults move

shoreward for spawning during spring. As water temperatures warm in late spring, they move back into deeper waters. Yellow perch travel in loosely formed schools throughout their lives (Simpson and Wallace, 1982; Wydoski and Whitney, 1982).

Diets of young yellow perch were found to overlap with juvenile smolt diets (Bennett et al., 1997b). A major portion of the yellow perch diet in Lower Granite Reservoir consisted of dipterans (Bennett et al., 1997b). Adults will switch to piscivory if prey species of appropriate size are present (Wydoski and Wallace, 1979) and unidentified fish which could have been smolts have been found in yellow perch stomachs (Bennett and Shrier, 1986).

Although not considered a good fighter, the firm, white, mild-tasting flesh of yellow perch makes it a desirable sport fish (Simpson and Wallace, 1982; Wydoski and Whitney, 1970). In fact, although not abundant (Bennett, 1991; Bennett et al., 1983; Bennett et al., 1997a; Bennett et al. 1997b; Dresser, 1996), yellow perch are among the top four sought-after resident sport fish in the lower Snake River reservoirs (USFWS, 1993a). In 1997, yellow perch were the fourth most often caught resident species in the lower Snake River reservoirs (U. of Idaho et al., 1998). The majority of this catch (74.7 percent) was in Ice Harbor Reservoir and decreased progressively upstream (15.3 percent in Lower Monumental, 8.1 percent in Little Goose, and 2.0 percent in Lower Granite reservoirs).

Walleye

Walleye (*Stizosteidion vitreum*) became established in Lake Roosevelt in the 1950s and dispersed downstream into the Columbia River (Zook, 1983, cited by Mullan et al. 1986). Walleye are a major salmonid predator in John Day Reservoir, but not in the Snake River reservoirs (Shively et al., 1991). Although walleye reportedly are caught, they have not been positively identified in the Snake River. None were caught in sampling efforts of Bennett et al., 1997a; Bennett et al., 1997b; Bennett et al., 1988a; Bennett et al., 1988b; Bennett et al., 1983; and Dresser, 1996.

5.2.3 Predation on Juvenile Salmonids

Although, several species present in the lower Snake River reservoirs prey on salmonid smolts as they emigrate toward the ocean, predation has not been deemed a major source of mortality in Lower Granite Reservoir (Bennett et al., 1997a; Naughton, 1998; Ward et al., 1995). Similarities between the four lower Snake River facilities and reservoirs make it likely the same is true for the other three reservoirs as well. Northern pikeminnow, smallmouth bass, channel catfish, white crappie, black crappie, and possibly yellow perch and white sturgeon, at least occasionally, prey on juvenile salmonids (Anglea, 1997; Bennett, 1991; Bennett et al., 1997a; Bennett et al., 1988a; Bennett et al., 1988b; Bennett et al., 1983; Bennett and Shrier, 1986; Chandler, 1993; Naughton, 1998). White crappie, black crappie, yellow perch, and white sturgeon predation on salmonids is extremely rare and even less significant than with these other species.

5.2.3.1 Smallmouth Bass

Smallmouth bass are the most abundant salmonid predator present in the lower Snake River reservoirs (Bennett et al., 1988a; Shively et al., 1991). Anglea (1997) and Bennett et al. (1997b) estimated approximately 21,000 smallmouth bass 175 mm (6.9 inches) or greater in length were present in Lower Granite Reservoir in 1994 and 1995, two to three times the estimated number of northern pikeminnow (Cichosz, 1996). Zimmerman (in press) found smallmouth bass abundance increased significantly with movement upstream from Columbia River reservoirs to those on the Snake River. However, actual

predation on salmonids has been shown to be low (Bennett et al., 1983; Bennett and Naughton, 1998; Shively et al., 1991). Shively et al. (1991) found overall consumption rate to be 0.01 salmonids per fish per day for the four Snake River reservoirs. The consumption rate in the free-flowing sections of the Clearwater and Snake rivers was also 0.01 salmonids per fish per day. Predation of salmonids was seen primarily in larger smallmouth bass; of those which ingested salmonids, 90 percent were 280 mm (11.0 inches) or longer in length (Shively et al., 1991). Smallmouth bass consumed mainly non-salmonid fish and crayfish (Zimmerman, in press).

Environmental factors, such as water temperature and turbidity, may explain the low predation rates on salmonids found in these reservoirs. Smallmouth bass do not actively feed at water temperatures of 10°C (50°F) or lower (Bennett, 1991; Bennett et al., 1997b; Bennett et al., 1988b; Bennett and Shrier, 1986; Carlander, 1977; Coutant, 1975). During the main smolt outmigration through the lower Snake River reservoirs, water temperatures are often at 10°C (50°F) or less (Bennett, 1991). Smallmouth bass are sight feeders; thus, increased turbidities during spring outmigration likely decreases predation effectiveness (Gregory and Levings, 1998; Zaret, 1979, as cited in Shively et al., 1991).

5.2.3.2 Northern Pikeminnow

Northern pikeminnow, although less abundant than smallmouth bass, are likely the major salmonid predator in lower Snake River reservoirs (Chandler, 1993; Shively et al., 1991). Their predation rates on salmonids, however, are also low and it appears their population numbers are declining (Bennett et al., 1997b; Bennett and Naughton, 1998; Cichosz, 1996; Parker et al., 1995; Ward et al., 1995). Predation, when it does occur, tends to be associated with unnatural events, such as hatchery releases liberating hundreds of thousands of smolts over a short time frame in a constricted space (Shively et al., 1996), or unnatural obstacles such as the dams and associated structures. Ward et al. (1995) found approximately 33 percent of northern pikeminnow predation on juvenile salmonids in the lower and mid-Columbia and lower Snake rivers occurred in the tailrace boat restricted zones (the area immediately downstream of each dam).

Bennett and Naughton (1999) sampled 1,515 northern pikeminnow in the tailrace of Little Goose Reservoir, the forebay of Lower Granite Dam, and the moving water areas of the Clearwater and Snake river arms from April through August 1996. They found only two smolts in their stomach samples.

Chandler (1993) found much higher predation rates by northern pikeminnow on salmonids than did Naughton (1998). He estimated annual loss of smolts to northern pikeminnow was 128,641 or 35.7 smolts per ha. Salmonids were the most important prey item, by weight, for northern pikeminnow during April, May, and June, 1987 through 1991 pooled (Chandler, 1993). This coincides with the time period when most smolts outmigrate. Consumption estimates of salmonids were highest in April (0.17 salmonids per northern pikeminnow) and declined in May (0.11) and June (0.06). Although these figures are much higher than Naughton's results, overall predation was still considered low (0.6 percent of the number of smolts outmigrating annually).

Shively et al. (1991) also found higher predation rates by northern pikeminnow on salmonids than did Naughton (1998). Of the 1,408 northern pikeminnow stomachs sampled in the Snake River from Ice Harbor Dam upstream to free-flowing water in both the Snake and Clearwater rivers, 885 (63 percent) contained salmonids. Northern pikeminnow collected in the tailrace and forebay areas, particularly in the boat-restricted zones, consumed the highest numbers of salmonids. Those collected in the mid-reservoir areas contained no salmonids.

Despite similar northern pikeminnow predation rates in lower Snake River reservoirs to those found in Columbia River reservoirs (Petersen et al., 1990), overall predation was one half to one third lower (Shively et al., 1991; Ward et al., 1995). This was attributed to water temperature, northern pikeminnow size, and possibly fewer salmonids. Colder water temperatures in the Snake River lead to slower digestive rates, limiting the number of prey an individual northern pikeminnow can consume. Also, northern pikeminnow caught in the Snake River were approximately 10 percent smaller than those caught in the Columbia River. Northern pikeminnow piscivory on salmonids increases with size (Vigg et al., 1991; Zimmerman, *in press*), and in Lower Granite Reservoir, northern pikeminnow less than 349 mm (13.7 inches) long were not significant predators (Chandler, 1993). Chandler (1993) found only a small percentage of northern pikeminnow 349 mm (13.7 inches) or less in length preyed on salmonids. Numbers of salmonids available as prey in the Snake River, particularly at Ice Harbor and Lower Monumental dams, may be fewer than in Columbia River reservoirs because of the transportation program at Lower Granite and Little Goose dams (Shively et al., 1991).

Discrepancies in predation rates between the above studies could be attributable to differences in sampling procedures, flow conditions, or population size and structure. Shively et al. (1991) and Naughton (1998) relied on electrofishing to collect samples, whereas Chandler (1993) employed gillnets. Although this could influence results, given the number of stomachs examined, it is doubtful results would be particularly biased. Low flow conditions and, therefore, slow velocity can increase salmonid exposure to predators up to as much as three times (Ebel, 1977, as cited in Bennett et al. 1988a). Much of Chandler's data were collected during relatively low flow years, and Shively et al. (1991) sampled during an average water year. Naughton collected his data during two high flow years. Chandler and Shively et al. reported the highest rates of predation occurred in April. During 1996, Naughton found flows were too high to successfully sample the boat restricted zones. Finally, the sport-reward program has been in effect in the lower Snake River since 1991. Removal of 132,542 northern pikeminnow greater than 275 mm (10.8 inches) from the four lower Snake River reservoirs (unpublished data, WDFW) has reduced numbers of larger northern pikeminnow, likely reducing predation.

Northern pikeminnow, however, is an opportunistic predator (Chandler, 1993), and can quickly capitalize on an available prey source (Shively et al., 1996). Within 1 week of a hatchery release of 1.1 million yearling chinook in the Clearwater River of Idaho, 86 percent of the gut contents of northern pikeminnow sampled 60 to 66 river km (37 to 41 river miles) downstream were salmonids.

5.2.3.3 Channel Catfish

Channel catfish, likely the least abundant of the three major salmonid predators, had the highest incidence of occurrence of salmonids in stomach samples (Bennett et al., 1988b; Bennett et al., 1983). Steelhead smolts comprised 73 percent of all prey items in spring stomach samples of channel catfish (Bennett et al., 1988b). Only one chinook was found in the same samples. Predation by channel catfish is also curtailed at water temperatures less than 10°C (50°F) (Bennett, 1991).

5.2.3.4 Piscivore Predation of Juvenile Fall Chinook

Although predation does not currently appear to be a significant source of mortality to the majority of outmigrating salmonids in lower Snake River reservoirs, a separate discussion on impacts to the threatened Snake River fall chinook is warranted. Unique life history characteristics of this fish make it easily the most vulnerable salmonid in the system. Subyearling fall chinook move into the

reservoirs at a smaller size than most other salmonids; they rear in the reservoirs; and they tend to reside in and travel through the reservoirs during periods of higher water temperatures, lower flows, and lower turbidities. Their smaller size makes them vulnerable to a wider range of predators. Longer residence time in the reservoirs increases the likelihood of encountering a predator. Additionally, predators are more actively foraging and, therefore, will have the highest consumption rates during the warmer summer months when juvenile fall chinook are outmigrating through the lower Snake River reservoirs (Isaak and Bjornn, 1996; Ward et al., 1995).

5.3 Invertebrates (Post-Dam)

Benthic diversity in the lower Snake River reservoirs is low and is dominated by midges (Chironomidae) and worms (Oligochaeta) (Annex A). The density of other taxa such as scuds (Amphipoda; *Corophium* sp.) and roundworms (Nematoda) is very low. Total biomass is highly influenced by worms and ranges from 2 g/m^2 (18 lb/ac) to 20 g/m^2 (180 lb/ac) in Lower Granite Reservoir (Bennett et al., 1988b; Bennett et al., 1983). With the exception of worms, benthic density decreases with depth (Pool and Ledgerwood, 1997). Pool and Ledgerwood (1997) found 76 taxa of invertebrates present in Lower Granite Reservoir. However, three taxa, worms, midges, and to a lesser degree, bivalves, comprised 93 percent of all organisms counted (Figure 5-16). Pool and Ledgerwood (1997) felt the benthic community in soft substrates has remained fairly stable over the last 20 years.

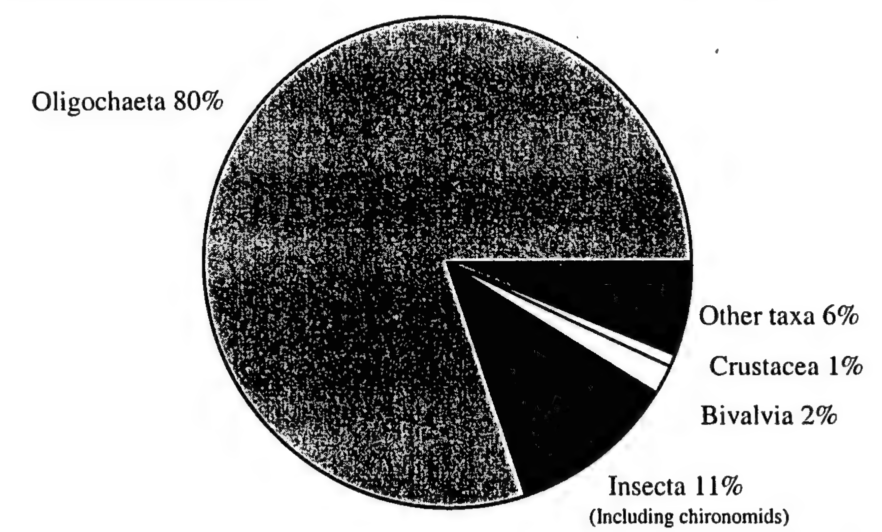

Figure 5-16. Relative Composition, Percent by Number, of Major Benthic Taxa Found in Three Soft-Substrate, Shallow-Water Sampling Areas (Pooled Data) of Lower Granite Reservoir, 1994-1995

Source: Pool and Ledgerwood, 1997

Mollusc diversity has been greatly reduced by the impoundment of the Snake River. Prior to impoundment, the lower Snake River likely supported 34 species of molluscs, 33 of which were native to the river (Frest and Johannes, 1992). Limited sampling done during the test drawdown produced only seven mollusc species (Frest and Johannes, 1992). The current mollusc fauna is dominated by the Asian clam *(Corbicula fluminea)*, which became established in the Columbia River

in the 1940s (Frest and Johannes, 1992). The California floater (*Anodonta californiensis*), a species of concern for the USFWS, was also found in the sampling. The shortface lanx (*Fisherola nuttallii*) as well as three other snails (western floater *A. kennerlyi*, knobby rams horn *Vorticifex effusa*, and creeping ancylid *Ferrissia rivularis*), and the bivalve, western ridged mussel (*Gonidea angulata*) were also found in small numbers.

Crayfish appear to be well established throughout the lower Snake River reservoirs (Bennett et al., 1983). The signal crayfish (*Pasifacticus leniusculus*), found in the lower Snake River, is an aggressive, non-burrowing, highly reproductive species (Lowery and Holdich, 1988). They likely are an important link in the trophic dynamics of the reservoir in that they can capitalize on the abundant worm population (Bennett et al., 1991). Crayfish, in turn, provide an important food source for several fish species including northern pikeminnow, white sturgeon, channel catfish, and smallmouth bass. Bennett et al. (1997) found crayfish densities were highest in the upper portion and lowest in the downstream portion of Lower Granite Reservoir. They attributed this to differences in available substrate: downstream portions had higher percentages of silt and fine substrate.

5.4 Terrestrial Resources (Post-Dam)

5.4.1 Vegetation/Habitat

5.4.1.1 Riparian Habitat

Based on 1997 aerial photography, a total of about 745 ha (1,840 acres) of woody riparian habitat was found along the lower Snake River (Table 4-1). This is about 55 percent of the approximately 1,329 ha (3,285 acres) present before inundation. Plantings and irrigation on HMUs accounted for 206 ha (510 acres) of the woody riparian habitat. The remainder was due to plantings on other facility lands, habitat already present after inundation (mainly at the mouths of tributaries), and natural revegetation along the reservoir and tributary shorelines. Woody riparian habitat accounted for only 407 ha (1,006 acres) in 1987 (USFWS, 1991). Much of the increase seen between 1987 and 1997 was due to several reservoir drawdowns which occurred since 1987 and which allowed significant amounts of willow, false indigo (*Amorpha fruticosa*), and other woody species to become established. Some of this vegetation drowned out following the drawdowns; however, several hundred acres remain. While woody riparian acreages currently total just over one-half of the total lost, the quality of this habitat for wildlife is still lower than that lost. Also, this riparian habitat is more fragmented than what occurred prefacility. Hanson et al. (1990) found decreases in diversity and changes in wildlife species composition in more fragmented riparian corridor landscapes.

Riparian vegetation that has become established along the reservoirs is typically more drought tolerant, includes more shrubs than pre-impoundment vegetation, and often lacks any tall tree component (USFWS, 1994). Russian olive (*Elaeagnus angustifolia*) is now the dominant tree species. Black cottonwood, black locust, hackberry, and white alder are also present, though scattered and in small numbers. Some of the riparian shrubs coming back in along the reservoir shorelines include coyote willow and other shrubby willows, false indigo, and red-osier dogwood (*Cornus stolonifera*). Along the shorelines, woody riparian communities occur primarily at and just above the high-water line, because of fluctuating water levels, steepness of slopes, and adjacent road and railroad right-of-ways.

Currently, emergent wetlands are much more abundant, with 139 ha (353 acres) present in 1997. This increase is likely because of several factors: (1) abundant slack water which causes sediments carried into the reservoirs to accumulate and create good conditions for wetland vegetation

development, especially at the mouths of tributaries, (2) several embayments and backwaters which also allow wetland development, (3) drawdowns which allowed wetland vegetation to get established, and (4) runoff and seeps from nearby irrigated HMUs. There were only 42 ha (103 acres) of emergent wetlands at the upper two facilities, compared with 101 ha (250 acres) (71 percent) at the lower two facilities. This is because of more open water areas, backwaters, embayments, and riverside channels along those lower reservoirs (Corps, 1992).

While hunting pressure was fairly light along the lower Snake River before the dams were constructed, it is now heavy at the intensively managed HMUs. This is because the lands are open to the public for hunting and these HMUs provide good quality habitat for upland game birds.

5.4.1.2 Upland Habitat

Currently there are over 2,612 ha (6,454 acres) of shrub-steppe habitat present in and along the study area (Table 4-1). Characteristic vegetation of this habitat includes big sagebrush, gray rabbitbrush (*Chrysothamnus nauseosus*), and cheatgrass. Grassland currently occupies nearly 3,966 ha (9,800 acres) within the study area and is comprised mainly of cheatgrass and bluebunch wheatgrass (USFWS, 1991). Grazing was removed from most of the facility lands in the late 1970s following fencing under the Compensation Plan; however, 69 cattle watering corridors were established across facility lands to allow livestock access to the Snake River for watering. While shrub-steppe and grassland habitat conditions have not changed much for the lower two facilities since grazing was removed, they have improved for the upper two facilities. This is based on the HSI values for western meadowlark (Table 5-1), the species representing these habitat types. The reason for the difference in improvement may be because the lower facilities have lower annual precipitation, resulting in a longer recovery period for the habitat following cessation of grazing.

Currently, about 130 ha (320 acres) of agricultural land is present in the study area. All of this land is being managed for wildlife with a mixture of cropland, alfalfa and grass pastures, and food plots. Food plots are primarily small patches of crops which are rotated among corn, sunflowers, and grain sorghum. Other crops sometimes used in food plots include wheat and millet.

5.4.1.3 Habitat Effects From March 1992 Drawdown Test

In March 1992, drawdown tests were conducted for Lower Granite and Little Goose reservoirs to gather information regarding the physical effects of lowering reservoirs substantially. Lower Granite and Little Goose reservoirs were drawn down 11 m (36 feet) and 4 m (12.5 feet) below MOP, respectively, for 1 month (Corps, 1993). Aside from testing physical effects from the drawdown, the Corps and others conducted several studies to determine some of the biological effects of this particular drawdown (Corps, 1993; Phillips, 1993; Cushing, 1993). Phillips (1993) conducted a study to determine the effects on vegetation from this significant water level drop and also from operating all of the reservoirs near MOP during most of the growing season. As mentioned earlier, the NMFS 1995 Biological Opinion now states that Snake River reservoirs should be operated at MOP from April 10 until about late August to reduce travel times for juvenile anadromous fish.

Phillips (1993) found a variety of vegetation responses to the drawdown and MOP operations, depending on factors such as the particular reservoir and aspect of the study site. At the Chief Timothy HMU, no vegetation was established during the drawdown on the south side of the island. The HMU shorelines below ordinary high water line (OHWL) at Lower Granite and Little Goose

Table 5-1. Average Habitat Suitability Indices (HSI) for Preproject (1958) and Existing (1987) Conditions[1/]

	Lower Two Facilities[2/]		Upper Two Facilities[3/]	
Evaluation Species (covertype or species group)	**Preconstruction (1958) HSIs**	**Existing (1987) HSIs**	**Preconstruction (1958) HSIs**	**Existing (1987) HSIs**
Downy woodpecker (Riparian forest)	1.00	0.03	1.00	0.59
Song sparrow (Riparian forest understory)	1.00	1.00	0.95	0.96
Yellow warbler (Palustrine scrub-shrub)	0.81	0.77	0.55	0.64
Marsh wren (Emergent wetland)	0.27	0.27	0.00	0.00
Song sparrow (Mesic shrubland)	0.84	0.71	1.00	1.00
Western meadowlark (Shrubsteppe/grassland)	0.34	0.32	0.35	0.52
River otter (Furbearer)	0.46	0.45	0.24	0.46
Mule deer (Big game)	0.29	0.36	0.34	0.34
California quail (Upland game bird)	1.00	0.16	0.95	0.35
Ring-necked pheasant (Upland game bird)	0.39	0.29	0.46	0.63
Chukar (Upland game bird)	0.00	0.01	0.80	0.79
Mallard (Waterfowl)	0.28	0.21	0.33	0.27
Canada goose (Waterfowl)	0.35	0.21	0.29	0.12

1/ Note: Indices were calculated from habitat evaluation procedures (HEP) analyses conducted for the lower Snake River study area.

2/ Data from USFWS (1991).

3/ Includes Ice Harbor and Lower Monumental facilities.

Includes Little Goose and Lower Granite facilities established on them in March 1992.

reservoirs (nine HMUs) had living and dead (from the previous year) plants in March 1992, while none of the HMUs at Lower Monumental and Ice Harbor reservoirs (six HMUs) had any plants.

As the lowered pool phase progressed from April through July, there were often significant changes in vegetation communities (Phillips, 1993). For example, speedwell (*Veronica* spp.) formed a solid carpet at one site along Lower Granite Reservoir and was succeeded by a solid carpet of two species of smartweed (*Polygonum* spp.), with speedwell as a ground cover. Table 5-2 shows that as time progressed, the diversity of plant species classified as abundant, increased. The lowered pool elevation condition upstream of Lower Granite and Little Goose dams created substrate and space for pioneering vegetation. This pioneering vegetation was extremely diverse from both biodiversity and structural perspectives (Phillips, 1993). Representative species of various groups included:

Table 5-2. Plants Classified as Abundant and Found below the Ordinary High-Water Mark at Fifteen Study Sites along the Four Lower Snake River Reservoirs

March	April	May	June	July
cattail - 1[1/]	cattail – 3	cattail – 3	coyote willow – 5	marshpepper smartweed – 7
reed canarygrass – 1	veronica – 2	veronica – 3	Lady's thumb – 4	Columbia sedge – 5
Lady's thumb – 1	false indigo – 2	Lady's thumb – 3	marshpepper smartweed – 3	Lady's thumb – 3
soft rush – 1	reed canarygrass – 1	reed canarygrass – 2	mayweed chamomile – 2	mayweed chamomile – 3
	soft rush – 1	false indigo – 1	false indigo – 1	coyote willow – 3
	cheatgrass – 1	soft rush – 1	cattail – 1	short-pointed flatsedge – 2
	broad-leaved pepperweed – 1	coyote willow – 1	Russian thistle – 1	cattail – 2
	yellow sweetclover – 1	Columbia sedge – 1	common purslane – 1	rabbitfoot grass – 2
		narrow-leaved dock – 1	stout sandspurry – 1	false indigo – 2
				Watson's willow-weed – 2
				western goldenrod – 2
				soft rush – 1
				reed canarygrass – 1
				white clover – 1
				veronica – 1
				white sweetclover – 1
				Russian thistle - 1

Note: These plants were found during and after the March 1992 drawdown and minimum operating pool operations.
Source: Based on Phillips (1993).
1/ Number of study sites where species were recorded as abundant.

- Trees—black cottonwood, white alder, peachleaf willow (*Salix amygdaloides*), black locust, Russian olive, and bitter cherry (*Prunus emarginata*)
- Shrubs—coyote willow, false indigo, and red-osier dogwood (*Cornus stolonifera*)
- Emergent wetland plants—cattail, softstem bulrush (*Scirpus validus*), soft rush (*Juncus effusus*), Columbia sedge (*Carex aperta*), and short-pointed flatsedge (*Cyperus acuminatus*)
- Annual grasses—cheatgrass; and, forbs—smartweeds (*Polygonum* spp.), speedwell, mayweed chamomile (*Anthemis cotula*), teasel (*Dipsacus sylvestris*), cocklebur (*Xanthium strumarium*), and annual sunflower (*Helianthus annuus*)
- Perennial grasses—reed canarygrass and rabbitfoot grass (*Polypogon monspeliensis*).

There was little overlap between plants actually observed growing following drawdown in 1992 at certain sample sites (Phillips, 1993) and seeds found in sediment samples at the same sites (Robbercht, 1998). This difference may be due to a couple of factors: (1) the lack of viability of some of the seeds in the seedbank, (2) plants observed in the earlier study were mainly from seeds recently windborn, as opposed to sprouting from seeds already present in the sediments, or (3) weather or some other ecological phenomenon.

Cushing (1993) found that within 1 year of the Lower Granite and Little Goose reservoir drawdowns, significant revegetation had occurred. Revegetation had included a wide diversity of annual forbs, sedges, and woody plants such as willow, false indigo, and white alder at riparian sites with bulrush, cattails, and reed canary grass on mudflats adjacent to wetlands.

Nearly 3,000 individual plants of five wetland plant species were planted at different elevational gradients, from OHWL to MOP, during the March 1992 drawdown (Phillips, 1993). Many of the plants thrived initially and even flowered and produced seed, with slough sedge (*Carex obnupta*) demonstrating the best survival. However, nearly every plant was dead by late July, especially 1 and 1.5 m (3 and 5 feet) below OHWL levels. This indicated that reduced nutrients, water-holding capacity, and perhaps other variables may be working to prevent long-term survival of the plant species tested (Phillips, 1993).

5.4.1.4 Exotic Plants

Most of the plant species growing on exposed substrate after the March 1992 drawdown (64 percent) were exotics, with reed canarygrass the fastest and most aggressive colonizer (Phillips, 1993). Twenty-five of the 46 plant species (54 percent) found as seeds in substrate cores below the OHWL were exotic species (Robberecht, 1998). Many of these exotic species can be viewed as "weedy" and undesirable in the plant community. Various weeds present within the study area are classified as Class A and Class B noxious weeds; this include Scotch thistle, bull thistle (*Cirsium vulgare*), Canada thistle (*Cirsium arvense*), various knapweeds (*Centaurea* spp.), yellowstar thistle (*Centaurea solstitialis*), rush skeletonweed (*Chondrilla juncea*), false indigo (*Amorpha fruticosa*), and purple loosestrife (*Lythrum salicaria*) (Corps, 1997b). The Corps is actively controlling noxious and other weeds on facility lands within the study area with mowing, burning, and chemical applications. While weeds on much of the facility lands are relatively under control, some surrounding lands have serious weed problems and provide a constant seed source for Corps facility lands, especially from those weeds with wind-borne seed dispersal (such as knapweeds, yellowstar thistle, and other thistles). Also, disturbance factors such as roadways and cattle concentration areas can help perpetuate noxious weed problems within the study area (Corps, 1997b).

False indigo is a shrub native to North America, but not the Pacific Northwest. In Washington, this species is usually found along shorelines of fluctuating water bodies such as rivers and reservoirs. It can form dense thickets, crowding out native vegetation and creating a monoculture. While listed as a noxious weed, it does provide some wildlife benefits (escape and nesting cover for some birds) and can help stabilize shorelines.

Purple loosestrife is a very aggressive weed which has been replacing much of the native vegetation in some wetlands in eastern Washington, in recent years. While reservoirs and other slow-moving water courses with broad alluvial deposits provide good habitat for this species, fast-flowing streams and rivers do not (Parker and Burrill, 1992). It is currently only found in fairly small patches throughout the study area and was not found during drawdown studies (Phillips, 1993) or during seedbank studies (Robberecht, 1998). However, it could possibly become more widespread in the future. Efforts at biological control of this plant are beginning to show some progress (Coombs, 1996).

5.4.1.5 Habitat Evaluation Procedures

An estimate of HUs that had been replaced through the acquisition of additional facility lands, and management of those lands and existing facility lands, was based on a HEP analysis conducted at

sample sites associated with the upper two and the lower two reservoirs (USFWS, 1991). Some of the management activities being conducted to improve habitat have been driven by the HEP models; for example, distance to winter food is being optimized for pheasants in some cases with the strategic placement of food plots. Certain compensation criteria can be found in the LOA and USFWS (1991), such as the crediting of acquisitions with only 50 percent of the HUs present on them, unless it was high quality riparian/wetland habitat potentially threatened by land use changes, thereby allowing 100 percent HU credit.

An average HSI was derived for each species for the upper and lower reservoirs and converted to HUs by multiplying by appropriate cover type acreages from 1987 aerial photography (USFWS, 1991) (Table 5-3). In 1997 and 1998, the Corps, USFWS, and WDFW reevaluated HUs on project lands and off-facility lands based primarily on cover-type acreage from 1997 aerial photography and on some changes deemed necessary with some HSI determinations (Table 4-2). There was a significant increase in many of the HUs from 1987 to 1997. Most of this increase is from the several off-project HMUs purchased and developed since the 1991 report.

Table 5-3. Acreages of Habitat Types at the Four Lower Snake River Facilities Based On Cover Type Information [1/]

Habitat Type	Prefacility (1958)	1987	1997
Riparian forest	710.8	129.2	468.0
Palustrine scrub-shrub	1,736.6	281.2	592.3
Mesic shrub	837.3	595.6	781.8
Perennial forb and grass (AFG)	1,915.7	1,117.2	769.4
Palustrine Emergent	9.9	54.0	353.2
Shrub-steppe	7,674.3	4,456.3	6,453.6
Grassland (steppe)	13,288.7	9,041.2	9,775.4
Agricultural Land	4,643.3	468.2	319.6

1/ Based on USFWS (1991) and cover typing completed by USFWS and Corps in 1997.

Table 5-1 shows that some of the HSI values estimated for the upper and lower facility were much lower than those estimated for prefacility conditions. For example, the downy woodpecker and California quail HSIs were both estimated to be 1.00 for the prefacility conditions for the lower two projects; however, the existing conditions for the lower two facilities were 0.03 for the woodpecker

and 0.16 for the quail. Much of this difference appears to be from slow development of woody vegetation at these facilities and poor species and structural diversity. Canada goose HSIs went down by about one-third for the lower projects and about two-thirds for the upper facilities. This was mostly because of the inundation of islands. Average otter HSI for the upper facilities increased from 0.24 to 0.46 for the existing condition. This was from improved denning habitat due to extensive placement of riprap along the shorelines of the reservoirs. Some of the other differences in HSIs, either increases or decreases, are more difficult to explain. They would likely be easier to understand if HSIs were calculated for each HMU using measured HEP data collected at that HMU.

At this point, compensation losses from reservoir inundation have not been met for 7 of the 12 species modeled. Nearly 29,000 HUs remain uncompensated with the majority for California quail (20, 986 HUs). However, less than 3,200 HUs have exceeded compensation goals. With the exception of the chukar and Canada goose, the species with uncompensated losses (downy woodpecker, yellow warbler, California quail, ring-necked pheasant, and song sparrow) are either dependent on or prefer riparian habitat for some life requisite. While most of these species do not need habitat associated with water, the riparian habitat provides important cover and other habitat components. In this arid environment, riparian areas are often the only place where adequate habitat occurs for many wildlife species. Since only 43 percent (905 ha [2,236 acres]) of the riparian habitat has been replaced, with much of this with lower values than that which was lost, it is not surprising that compensation deficits still persist for associated species. Considerable effort at replacing riparian habitat values has fallen far short in terms of acres and HUs of associated species.

5.4.2 Wildlife Resources

There have been several changes in the species composition and populations since the impoundment of the four lower Snake reservoirs. For example, waterfowl distributions, numbers and species have changed. Some species were dependent on riparian habitats that were inundated. Many of these species have begun to come back with the development of HMUs and natural revegetation along the shorelines, although the wildlife communities and their distribution are not the same as they were pre-impoundment.

Lewke and Buss (1977) concluded that birds forced from riparian habitats due to inundation would not be able to reestablish themselves in remaining above-pool habitats, which were already filled to capacity. Furthermore, the shoreline along the reservoir is much steeper and has poorer and more shallow soils then that which was inundated, resulting in a lower quality riparian/floodplain habitat when it fully develops (Lewke and Buss, 1977).

The irrigated HMUs have been used to attempt to replace some of the lost riparian habitat values that occurred with inundation by the four reservoirs. While some of these have been developed as planned, they are not an adequate replacement for native riparian/floodplain habitats for the following three reasons: 1) HMUs often incorporate the use of non-native species (for example, Russian olive), which are inferior to native riparian habitats for many wildlife species since they are usually more monotypic, result in less diverse habitat, and often do not provide the snags and cavities needed by several wildlife species. As discussed below, bird and small mammal populations, species diversity, and species richness are often highest in native riparian habitats. 2) Non-native species are often inferior to native species in providing food for many wildlife species. For example, fewer insects are often associated with non-native plant species (Kennedy and Wilson, 1969). 3) HMUs are usually distinct habitat islands with little, if any, connectivity with other similar habitats. This can be an

effective travel or migration barrier for some species; thus limiting dispersal and genetic diversity, or exposing individuals to increased predation risk when they attempt to move to other habitats.

5.4.2.1 Game Birds

The intensively managed HMUs provide excellent habitat for California quail, as do several vegetated drainages, but quail habitat is fairly limited in other areas (Corps, 1991). Some of the riparian areas developing naturally along the shorelines are beginning to provide habitat as well. The intensively managed HMUs would also provide excellent habitat for ring-necked pheasants. Lower Granite and Little Goose facilities provide the best habitat for chukars (Corps, 1992), although they typically utilize upland habitats instead of irrigated HMUs. Trees and shrubs on the irrigated HMUs and other areas with woody vegetation would provide good nesting habitat for mourning doves.

Where water sources are limited, young birds would be more susceptible to predation when moving from established cover to water until habitat develops along the shoreline, with corridors of appropriate cover leading to the water sources. Therefore, water sources were developed at several locations on facility lands.

Long stretches of shoreline (156 km or 97 miles) along the four lower Snake River reservoirs are currently lined with riprap, primarily to protect roads and railroads. Mudd et al. (1980) said that crossing of riprap to reach water may cause mortality of juvenile game birds, while placement of guzzlers in these areas may increase survival. This mortality may be reduced by strategically placing guzzlers near some riprapped sections and developing travel corridors to allow movement of game birds and other animals down to the water.

5.4.2.2 Waterfowl

A total of 27 species of waterfowl has been documented using the study area (Appendix A). The most common species found within the study area by Asherin and Claar (1976), in order of abundance, included Canada goose, mallard, American widgeon, and Barrow's goldeneye.

The major habitat change that has affected waterfowl in the Snake and Columbia River plains in the past few decades has been the development of large impoundments and irrigated agriculture (Ducks Unlimited, 1994). While this increase in reliable water has provided loafing and resting sites for waterfowl, impoundments have greatly altered flows in rivers and destroyed many riparian wetlands and river islands, chutes, and oxbows. The greatly increased acreage of cereal grains has also affected waterfowl numbers and distribution, especially mallards and Canada geese. Since that time, mallard populations have varied significantly, with peak estimates exceeding 900,000 in some years (USFWS, 1997).

Of the four lower Snake River reservoirs, Ice Harbor typically has the most waterfowl (mainly mallard and Canada geese) during migration and winter (with a high count of almost 16,000 mallards in December 1978) (unpublished aerial waterfowl counts by the USFWS and WDFW). This may be a result of Ice Harbor Reservoir being a waterfowl reserve where waterfowl hunting is prohibited. While waterfowl numbers drop off as you move upstream, the diversity of waterfowl increases.

Currently, geese nest in cliffs bordering the reservoirs (with this habitat more abundant in the upper half of the study area), on the remaining islands (with New York Island the last remaining island with significant nesting), and on artificial nesting structures placed on Corps' facilities lands. Nesting surveys conducted from 1974 through 1987 indicated that total numbers of nests found averaged 88.4 per year, with the low being 30 nests in 1974 and the high being 169 in 1980. Cliff nesting surveys

were initiated in 1978 with a steady increase from 6 nests in 1978 to 78 nests in 1994. In 1997, however, only 30 nests were found. This may be due to non-cliff-nesting geese replacing cliff-nesters (L. Boe, wildlife biologist, pers. obs.). Currently there is an abundance of brooding pastures, both natural and artificially managed on HMUs, other facility lands, parks, and golf courses. Many complaints have been received because of goose use of artificial pastures in and around Clarkston.

Gibson and Buss (1972) found that Canada goose nesting was greatly reduced after the construction of Lower Granite and Little Goose reservoirs. They attributed it to the inundation of islands and shore lands geese previously used for nesting. Large sand bars which supported willows, licorice (*Glycyrrhiza lepidota*), and cocklebur (*Xanthium strumarium*) were apparently an important component of Canada goose habitat and were abundant before impoundment. (Buss and Wing, 1966; Culbertson et al., 1971 in Lewke and Buss 1977).

5.4.2.3 Shorebirds

Shorebird use of the study area is currently limited due to the relatively steep shoreline of the reservoirs and the low number of sandbars and mudflats available. Only 10 shorebird species have been documented using the lower Snake River reservoirs (Appendix A). Asherin and Claar (1976) noted spotted sandpiper, killdeer, western sandpiper (*Caladris mauri*), and American avocet (*Recurvirostra americana*) using mudflats, gravel bars, or sandbars along the reservoirs. They also documented Wilson's phalarope (*Phalaropus tricolor*) in the reservoirs themselves. Rocklage and Ratti (1998) found killdeer, spotted sandpiper, and common snipe (*Gallinago gallinago*) in the area during the breeding season, lesser and greater yellowlegs in the fall, and killdeer and long-billed curlew in the spring.

5.4.2.4 Colonial-nesting Birds

Colony-nesting birds currently in the study area include gulls, terns, cormorants, herons, and cliff and bank swallows (Appendix A). There are several colonies of cliff and bank swallows all along the four reservoirs. Although there are several islands below Ice Harbor Dam on the McNary Reservoir which have large colonies of birds, there are no known colonies of gulls, terns, or cormorants, or rookeries of herons on the lower Snake River facilities. However, there were no known colonies or rookeries of these birds before the dams were built either.

5.4.2.5 Raptors

Twenty-three species of raptors have been documented in the study area (Appendix A). Rocklage and Ratti (1998) documented 17 species of raptors in the lower Snake River study area. Asherin and Claar (1976) found only 13 raptor species within the same area, with one species, burrowing owl, not seen in the previous study. During the summer of 1981, Fleming (1981) found 172 raptor nests of 10 species along the Snake River from Lewiston, Idaho, to Ice Harbor Dam. Beery (1974) found 61 nests of only six species from Lower Granite Dam down to Ice Harbor Dam. Although nesting information was not specifically recorded, Rocklage and Ratti (1998) recorded 209 raptors of 12 species present along the lower Snake River during the breeding season.

Asherin and Claar (1976) found American kestrel (*Falco sparverius*) and red-tailed hawk (*Buteo jamaicensis*) to be the most common raptors in the lower Snake River study area. Of the raptors seen during breeding bird censuses in 1997 along the lower Snake River, 94 (45 percent) were red-tailed hawks, 44 (21.1 percent) were American kestrels, and 28 (13.4 percent) were northern harriers (*Circus cyaneus*) (Rocklage and Ratti, 1998). However, red-tailed hawk and barn owl (*Tyto alba*)

were believed to be the most common nesting species near Lower Granite Reservoir (USFWS, 1989). A fall census revealed 35.5 percent red-tailed hawks, 24.6 percent northern harriers, 12.4 percent sharp-shinned hawks (*Accipiter striatus*), and 9.9 percent American kestrels (Rocklage and Ratti, 1998). Finally, Rocklage and Ratti found 51.7 percent red-tailed hawks, 27.8 percent northern harriers, and 9.9 percent American kestrels.

All of the above information indicates that a relatively diverse raptor population is present along the lower Snake River. All of the species documented either were found along the river before impoundment, or could find suitable habitat along an established riverine system (that is, prefacility conditions). McKern (1976) believed that the relatively high densities of songbirds and small mammals associated with riparian areas along the lower Snake and Columbia rivers provided important prey sources for many raptors.

5.4.2.6 Other Non-game Birds

Neotropical migratory birds (NTMBs) are species which breed in the United States and Canada and then migrate south to Mexico, Central or South America, or the Caribbean to spend the winter. They do not include waterfowl, shorebirds, or herons and egrets, even though some species in these groups also winter south of the Mexico-United States border. There is widespread concern about the future of NTMBs (Andelman and Stock, 1994) since many of these species have experienced large population declines due to habitat destruction on the breeding grounds, wintering areas, and along migration routes.

In Washington there are 118 NTMBs with 89 of them found in and adjacent to the facility area. Those which may be found in the study area are identified in Appendix A. For 87 (74 percent) of the NTMBs in Washington, information is lacking to determine long-term population trends. However, 15 species are known to have experienced long-term declines within Washington. All of these species, except for upland sandpiper and band-tailed pigeon, have been documented in the facility area. They include the following:

- ferruginous hawk (*Buteo regalis*)
- golden eagle (Aquila chrysaetos)
- killdeer (Charadrius vociferus)
- upland sandpiper (Bartramia longicauda)
- band-tailed pigeon (*Columba fasciata*)
- rufous hummingbird (*Selasphorus rufus*)
- eastern kingbird (*Tyrannus tyrannus)*
- barn swallow (*Hirundo rustica*)
- golden-crowned kinglet (*Regulus satrapa*)
- gray catbird (Dumetella carolinensis)
- solitary vireo (*Vireo solitarius*)
- orange-crowned warbler (*Vermivora celata*)
- yellow warbler (Dendroica petechia)
- Wilson's warbler (*Wilsonia pusilla*)
- chipping sparrow (*Spizella passerina*)

Some NTMB species are listed as threatened and endangered or species of concern to the USFWS and were documented in the project report. They include northern goshawk (*Accipiter gentilis*), western burrowing owl (*Speotyto cunicularia hypugea*), little willow flycatcher (*Empidonax traillii brewsteri*), and olive-sided flycatcher (*Contopus borealis*). The reasons long-term declines were not detected for these birds could be as follows:

- Little quantitative monitoring information was available for that species in Washington.
- Survey sample sizes were too small.
- The declining trends were not statistically significant for enough of the survey routes (Andelman and Stock, 1994).

Riparian ecosystems are key for many species of wildlife, especially for passerine birds in the arid west. Asherin and Claar (1976) found riparian habitats to have the highest bird species diversity indices and the most individuals during winter within the study area. Lewke (1975) also found this winter importance for weedy and riparian habitats at the Lower Granite facility site. Riparian habitats in Washington have been identified as priority areas for monitoring, research and management of NTMBs (Andelman and Stock, 1994). Native riparian habitat has, however, been relatively rare in the area due to land use policies and agricultural practices such as grazing, conversion to cropland, water diversion, and inundation by the lower Snake River reservoirs.

A study by the USFWS at Umatilla NWR (USFWS, 1997), just downstream of the Snake River confluence, showed that passerine birds prefer native-dominated (willow/cottonwood) riparian habitats over non-native-dominated (Russian olive) riparian habitats during migration. They suggest that the more diverse shrub and tree composition of native riparian areas creates better habitat for bird diversity, especially for NTMB, compared with Russian olive habitat. Along the middle Snake River, Brown (1990) found native willow sites to have higher bird species richness and density and more foraging and nesting guilds than Russian olive sites. Within willow/Russian olive mixed stands, all bird foraging guilds preferred willow over Russian olive.

Monda and Reichel (1989) conducted bird surveys at Lower Granite Reservoir following impoundment and found a decrease in riparian bird species and numbers, as expected. However, they also found an increase in bird species and numbers from the pre-impoundment study by Lewke and Buss (1977). These increases came primarily from aquatic and upland species. Upland species increases may have been a result of different survey routes that included a different composition of habitat. More rock talus and cliff habitat was present in the post-impoundment study, for example.

Currently, there about 143 ha (352 acres) of emergent wetlands present on facility lands. This increase from 4 ha (10 acres) preproject has likely benefited such wetland-dependent species as marsh wren, sora rail, and yellow-headed blackbird. Other species which have probably also benefited include red-winged blackbird, common yellowthroat, song sparrow, and shorebirds.

Rocklage and Ratti (1998) documented 92 species of birds during the breeding season within the study area, 94 species during the fall, and 91 species during the spring. They found significantly higher bird species richness during the breeding season and the fall for HMUs compared with the woody drainages which lead into the reservoirs. This is probably partly because the wooded drainages are relatively narrow strips of habitat and have been degraded by cattle grazing, whereas the HMUs are larger blocks of habitat. Furthermore, the HMUs are irrigated and often contain several food plots. In addition, they found that bird species richness and bird species diversity both generally increased upstream from the Ice Harbor facility to the Lower Granite facility. The Lower Granite facility had statistically

significantly higher bird species diversity (Simpson's Index) than only the Ice Harbor facility, while the Little Goose facility had significantly higher bird species richness (95 percent confidence interval) than only the Ice Harbor facility.

Asherin and Claar (1976) stated that low species diversity at the Ice Harbor facility was due to poor habitat. They said conditions were similar for the other reservoirs; however, those reservoirs had more tributaries with associated tree and shrub habitat. Rocklage and Ratti (1998) also found breeding bird species richness to be lower at Ice Harbor than any of the other facilities, with the only significant difference (95 percent confidence interval) being between the Ice Harbor and Little Goose facilities. Two diversity indices (Simpson's and Shannon-Wiener) also showed the Ice Harbor facility to have the lowest breeding bird diversity, with the only significant difference being between the Ice Harbor and Lower Granite facilities using the Simpson's index.

Weber and Larrison (1977) found that there were more bird species recorded from studies following impoundment than from pre-impoundment studies. They found, that reservoirs along the lower Snake River were attracting certain aquatic birds uncommon in the area before impoundments. The increase in aquatic habitat may partially explain why more bird species were found in recent studies than in preconstruction studies.

Seventy-nine breeding bird species were documented at HMUs, non-irrigated sites, and side drainages at the Ice Harbor and Lower Monumental facilities during a recent study (Rocklage and Ratti, 1998). At least 12 of the species not found in the prefacility study (Dumas, 1950) were most likely present due to the influence of the reservoirs. Also, at least two species (brown-headed cowbird and European starling) have simply increased their range into the study area since 1950. Furthermore, the Rocklage and Ratti study was more extensive and resulted in more species due to better coverage of the habitats. As mentioned earlier, nine species Dumas (1950) found before reservoir inundations, largely within the study area, were not found in the same area during the breeding season in the most recent study. This shows that the impoundments probably eliminated some bird species previously found along the lower Snake River. It further shows that the HMUs, at least to date, apparently do not have the necessary habitat components to attract these former breeding species. For example, species which would have been common prefacility, such as downy woodpecker and black-capped chickadee, were rarely seen during breeding season surveys. Until the HMUs and other riparian habitats mature and produce dead trees and snags, several species will continue to be rare. In contrast, however, the importance of the HMUs in helping provide riparian habitat is illustrated by the fact that 10 breeding species that depend on riparian habitat were found there, but not at the non-irrigated sites (Rocklage and Ratti, 1998). In addition, during the fall and spring, 20 and 13 species, respectively, that depend on riparian habitat were found at the HMUs, but not at the non-irrigated sites. Rocklage and Ratti (1998) state that their data showed that lower Snake River riparian habitats were more important as migratory habitat than breeding habitat.

While post-impoundment surveys indicate there are several more species of birds present than occurred preproject, this is from several new species being attracted to the associated reservoir habitat, range expansions of other species, intensive management on over 1,295 ha (3,200 acres) of HMUs, and more extensive and comprehensive surveying.

5.4.2.7 Big Game Animals

Aerial censuses conducted annually from 1978 to 1988 revealed maximum densities of approximately 5 deer/km^2 (13 deer/square mile) along the lower Snake River and associated tributaries in the winter of 1988 (Corps, 1990). Mule and white-tailed deer comprised 80 percent and 20 percent of the numbers,

respectively. Mule deer numbers increase moving upstream, with highest densities present on Lower Granite and the upper half of Little Goose facilities (Corps, 1979).

Compensation Plan mitigation efforts have improved deer habitat and numbers following widespread loss of habitat by inundation with reservoirs. Winter deer counts from Clarkston to Ice Harbor Dam ranged from 1,843 deer in March 1979 to 5,613 deer in February 1986, with at least some of this increase attributed to improved habitat from management actions (Corps, 1990).

The HMUs and, potentially, the remaining islands provide habitat for fawning. While there are deer in the study area throughout the year, currently, the primary use of the study area is for wintering, with deer moving up and down the canyon draws and into adjacent cropfields on a daily basis. Deer would use the HMUs, naturally developed riparian vegetation along the Snake River and tributaries, and vegetated draws. They rely on this habitat for resting and escape cover and winter browse. Winter deer range is considered to be of low to moderate quality (HSI of 0.36 for lower facilities and 0.34 for upper facilities), based on HEP analyses (USFWS, 1991).

Other big game animals which have been observed within the study area include elk, bighorn sheep, and mountain lion, although they would classified as uncommon to rare. There has been at least one sighting of moose (*Alces alces*) within the study area. All four of these species would most likely be found in the upper reaches of the study area.

5.4.2.8 Small Mammals

Eleven small mammal species have been documented in the study area, with two additional species likely present (Appendix A). Species caught during studies at the Lower Granite Reservoir study area (pre-impoundment) included, in decreasing order of abundance deer mouse (*Peromyscus maniculatus*), western harvest mouse (*Reithrodontomys megalotis*), vagrant shrew (*Sorex vagrans*), house mouse (*Mus musculus*), Great Basin pocket mouse (*Perognathus parvus*), montane vole (*Microtus montanus*), and long-tailed vole (*Microtus longicaudus*) (Lewke and Buss, 1977). The deer mouse was by far the most abundant species and accounted for 93 percent of the captures. The only small mammal caught in studies by Asherin and Claar (1976) at the Lower Granite Reservoir site was the deer mouse.

A recent survey within the study area found the following six species, in decreasing order of abundance: deer mouse, montane vole, western harvest mouse, vagrant shrew, Great Basin pocket mouse, and bushy-tailed wood rat (*Neotoma cinerea*) (Rocklage and Ratti, 1998). The deer mouse accounted for 74 percent of the individual small mammals captured.

Fleming (1981) conducted prey analyses based on pellets gathered at raptor nest sites along the lower Snake River and about 48 km (30 miles) of the Columbia River from the mouth of the Snake River to Umatilla, Oregon. Not surprisingly, he found the same small mammal species in pellets as identified in the above small mammal studies, except for the long-tailed vole. Montane vole was the number one prey item for several raptor species and for all species combined, followed in abundance by Great Basin pocket mouse.

Some small mammals were restricted to riparian habitats (such as vagrant shrew), and others occurred in riparian areas in relatively high numbers, such as deer mouse, western harvest mouse, montane vole, and house mouse (Asherin and Claar, 1976). Of 344 small mammals trapped, 268 (78 percent) were trapped in riparian areas. Small mammal diversity was also higher in native willow as compared with non-native (Russian olive) habitat. Numbers of most species were also higher in

native willow habitat, with deer mouse captures at 7.1 per 100 trap nights compared with 1.7 per 100 trap nights for Russian olive habitat (Asherin and Claar, 1976). The only exception was the house mouse, which was more numerous in Russian olive habitat.

5.4.2.9 Bats

Five species of bats have been documented in the study area, and five additional species are likely present since they have been documented, or suitable habitat is present in the vicinity (Appendix A). Asherin and Claar (1976) collected three species along stretches of the Snake River reservoirs wholly within the study area, including Yuma myotis, western pipistrelle, and pallid bat (*Antrozous pallidus*). Additional species confirmed for the area include small-footed myotis (*Myotis ciliolabram*) and Townsend's big-eared bat (*Plecotus townsendii*) (Cassidy et al., 1997). Five species which may also be present since they have been found in the vicinity, and suitable habitat is present, include long-legged myotis (*Myotis volans*), long-eared myotis (*Myotis evotis*), fringed myotis (*Myotis thysanodes*), hoary bat (*Lasiurus cinereus*), and big brown bat (Cassidy et al., 1997; Asherin and Claar, 1976). Most of these species commonly forage near or over water and roost in trees and shrubs (riparian areas along the lower Snake River), rock crevices, and buildings. However, the small-footed myotis, pallid bat, and western pipistrelle commonly forage around cliffs, rock outcrops, and dry canyons. The Yuma myotis, long-legged myotis, long-eared myotis, small-footed myotis, fringed myotis, and Townsend's big-eared bat are all listed as species of concern by the USFWS.

5.4.2.10 Furbearers

Coyotes and raccoons would be the most common terrestrial furbearers. Raccoon foraging and denning requirements depend largely on prey items found in riparian-type habitats and associated shallow water. Raccoons often use riparian habitats and the shoreline of reservoirs and free-flowing rivers. Coyotes, which are habitat generalists and opportunistic predators, are found throughout the facility area. They may concentrate in riparian areas and HMUs for the high small mammal populations here and would use them as travel corridors. Bobcats would also be found in the study area, although in much smaller numbers. They tend to forage in riparian zones during the winter (Bodurtha, 1992). Striped skunks would be found primarily on HMUs and in riparian corridors.

All four of the aquatic furbearers found in the study area before reservoir inundation are currently present (Appendix A). However, Asherin and Claar (1976) found their abundance to be low throughout the study area. Asherin and Claar (1976) also found muskrat and mink to be the least widely distributed aquatic furbearers after inundation, with mink only seen just outside of the study area. They believed this resulted from the lack of extensive riparian habitats following impoundment. Mink are dependent on riparian zones for foraging, where they capture large numbers of small mammals (Tabor et al., 1981). Beaver are relatively common along the lower Snake River reservoirs. They depend on woody riparian growth as a food source. Beaver lodges are rare, with most denning occurring in banks in association with at least sapling-sized trees.

Denning requirements for otter are not as stringent as for beaver. They use dens previously excavated by other species, although always in close proximity to water. Mack et al. (1994) found otters preferred large riprap, natural rock, and sand substrates for denning and latrine sites. Diets of otters in that study, based on scat analysis, were about 75 percent fish, 25 percent crayfish, and a small amount of birds and mammals. Molluscs would also be a component in the otter diet; however, they would not be detectable in scat analysis. Otters depend on prey found in shallow water and also on relatively dense bank cover that can be supplied by vegetation, woody debris and/or rocks. Heavy

riparian vegetation cover provides the best environment for both the cover and feeding requirements of this species.

5.4.2.11 Amphibians and Reptiles

Sixteen species of amphibians and reptiles have been documented in the study area, with two additional species likely there due to the presence of suitable habitat and documented presence in the vicinity (Appendix A). The racer was the most abundant reptile and the most widely distributed amphibian or reptile in the study area. It was found in a variety of habitats (Loper and Lohman, 1998; Asherin and Claar, 1976). Two other widely distributed species were the western toad and the Pacific tree frog. The most abundant amphibian was the long-toed salamander.

Amphibians and reptiles use a variety of habitats, with emergent wetlands and riparian areas especially important to amphibians. Most turtles, including the painted turtle (*Chrysemys picta*), the only turtle documented in the study area, are also closely related to water habitats. Surveys conducted in 1974 (Asherin and Claar, 1976) found 11 species of amphibians and reptiles within the lower Snake River study area. A recent survey by Loper and Lohman (1998) found 13 species in the study area. They noted no Pacific tree frog or long-toed salamanders along the shoreline of the reservoirs or in the temporary ponds and embayments adjacent to the reservoirs, although they are among the most common amphibians in the Pacific Northwest (Nussbaum, 1983). They speculate that water level fluctuations may have resulted in this notable absence. Their laboratory testing showed that Pacific treefrog eggs exposed for as long as 30 hours may have increased mortality. Furthermore, Asherin and Claar (1976) did note egg stranding and desiccation of the egg strings of the western toad in the middle Snake River.

Loper and Lohman (1998) found low species abundance and species richness for amphibians and reptiles in both riparian and upland habitats in the study area. While visual surveys showed higher amphibian numbers in riparian habitats, they expected a much greater relative abundance and species richness in riparian areas than in adjacent upland habitat. Some potential reasons for this disparity include:

- Current riparian habitats are only 20 to 30 years old and may not be fully colonized.
- Riparian vegetation communities may not be fully developed since they are relatively new.
- Some current riparian habitat is dominated by exotic plant species (for example, reed canarygrass (*Phalaris arundinacea*).
- Suitable riparian habitat is often isolated, with long reaches of riprap, bare shore, or very narrow bands of vegetation.

5.4.2.12 Threatened And Endangered Species

Listed Species

Sockeye salmon have been reduced to a remnant population that is close to extinction, and NMFS has listed them as endangered under the ESA. Snake River steelhead, Snake River spring/summer chinook, and Snake River fall chinook have all declined to a point where NMFS has listed them as threatened species.

Bald eagle (*Haliaeetus leucocephalus*)—Suitable habitat includes those areas that are close to water and that provide a substantial food base, such as along rivers with anadromous fish, good populations

of resident fish, abundant waterfowl and good mammal populations. In the study area, bald eagles are found along the shores of reservoirs and rivers. Territory size and configuration are influenced by availability of perch trees for foraging, quality of foraging habitat, and distance of nests from water supporting adequate food supplies.

The location of bald eagle nests in the Pacific recovery area is influenced by factors such as relative tree height, diameter, species, form, position on the surrounding topography, distance from water, and distance from disturbance (Anthony and Isaacs, 1989). Bald eagles usually nest in the same territories each year and often use the same nests repeatedly. Nest trees usually provide an unobstructed view of an associated waterbody and are often prominent locations on the topography. Snags, trees with exposed lateral limbs, or those with dead tops are often present in nesting territories. They are used as roosts, perch sites, or access points to and from the nest.

Bald eagle winter habitat is mostly associated with areas of open, ice-free water where fish are available and/or waterfowl congregate (Stalmaster, 1987). Additionally, eagles may be scattered through upland areas feeding on ungulate carrion, game birds and rabbits (Swenson et al., 1981). In areas where waterways do not freeze, adult eagles tend to remain on the territory year-round. A majority of the bald eagles wintering in central and eastern Washington are winter migrants (Fielder, 1992). Some move relatively short distances to lower elevations or inland for food sources. Most eagles that breed in the Pacific recovery area winter in the vicinity of their nests.

Bald eagles historically nested along the lower Snake River with a nest site in the 1950s located just upstream of the study area near the mouth of Captain John Creek. No bald eagle nesting has been documented along the reservoirs; however they do winter along the reservoirs. During the 1990 mid-winter bald eagle surveys 10 bald eagles were located along the lower Snake River (Corps, 1992).

Sightings of perched bald eagles at the John Day Reservoir found 93 percent of them in mature black cottonwoods and the remainder in black locust trees (USFWS, 1997). Waterfowl and fish were made up 100 percent of the winter diet of bald eagles on the Hanford Reach of the Columbia River (Fitzner and Hanson, 1979), and eagles along the lower Snake River would likely also depend on these prey items. Habitat loss and degradation continues to be the most significant long-term threat to all eagles in the recovery area (USFWS, 1986). Up to six adults and three immatures are seen along the Snake River each winter from Clarkston up to Heller Bar, which is about 24 km (15 miles) upstream from the study area boundary (M. Koliner, Canyon Birders, Clarkston, WA, personal communication).

Bull trout (*Salvelinus confluentus*)—Bull trout within the study area were listed as threatened on July 10, 1998. They are a wide-ranging species that formerly inhabited most of the cold lakes, rivers and streams throughout the western states and British Columbia. They are piscivorous and require an abundant supply of forage fish for vigorous populations. They exhibit four distinct life history forms: resident, fluvial, adfluvial, and anadromous. Resident bull trout spend their entire life cycle in the same (or nearby) streams in which they were hatched. Fluvial and adfluvial populations spawn in tributary streams where the young rear from 1 to 4 years before migrating to either a lake (adfluvial) system or a river (fluvial) system, where they grow to maturity (Fraley and Shepard, 1989). Anadromous fish spawn in tributary streams, with major growth and maturation occurring in salt water.

Bull trout display a high degree of sensitivity at all life stages to environmental disturbance and have more specific habitat requirements than many other salmonids (Fraley and Shepard, 1989; Howell and Buchanan, 1992; Rieman and McIntyre, 1993). Bull trout growth, survival, and long-term population persistence appear to depend particularly upon five habitat characteristics: 1) cover, 2),

channel stability, 3) substrate composition, 4) temperature, and 5) migratory corridors (Rieman and McIntyre, 1993).

Preferred spawning habitat consists of low gradient streams with loose, clean gravels (Fraley and Shepard, 1989). Fine sediments fill spaces between the gravel that are needed by incubating eggs and fry. An extremely long period of residency in the gravel (200 or more days) makes bull trout especially vulnerable to fine sediments and water quality degradation (Fraley and Shepard, 1989). Successful bull trout spawning and development of embryos and juveniles requires very cold water temperatures with spawning occurring below 9°C (48.2°F). Optimal incubating temperature seems to be from 2 to 4°C (35.6 to 39.2°F). Spawning occurs from August through November, and eggs hatch in late winter or early spring. Emergence occurs in early April through May, commonly following spring peak flows. Bull trout require complex forms of instream cover. Adults use pools, large woody debris, large boulders, and undercut banks for resting and foraging (Rieman and McIntyre, 1993). Juveniles also live on or within the streambed cobble (Oliver, 1979; Pratt, 1984) and use side channels and smaller woody debris in the water. Channels for moving between safe wintering areas and summer foraging areas are also necessary.

Extensive migrations are characteristic of the species (Fraley and Shepard, 1989; ODFW, 1993). Migratory bull trout facilitate the interchange of genetic material between populations, ensuring sufficient variability within populations. Migratory forms also provide a mechanism for restoring local populations extirpated due to natural and human-caused events (Rieman and McIntyre, 1993, citing others). Migratory bull trout have been restricted or eliminated because of stream habitat alterations, including seasonal or permanent obstructions; detrimental changes in water quality; increased temperatures; and the alteration of natural stream flow patterns. Migratory corridors tie seasonal habitat together for anadromous, fluvial, and adfluvial forms and allow for the dispersal of resident forms for recolonization of rebounding habitats. The disruption of migratory corridors, if severe enough, would result in the loss of migratory life history types and isolate resident forms from interacting with the metapopulation (U.S. Forest Service, 1993).

Major tributaries to the Snake River below Hells Canyon Dam that support bull trout subpopulations include 1) the Tucannon River, 2) Asotin Creek, 3) Grand Ronde River, 4) Imnaha River, 5) Clearwater River, and 6) Salmon River. Subpopulations that occur upstream of Hells Canyon Dam are generally small in size, fragmented, and isolated. Major tributaries that support bull trout subpopulations in this section of the Snake River Basin include 1) Pine Creek, 2) Malhuer River, 3) Powder River, 4) Weiser River, 5) Payette River, and 6) Boise River.

The only subpopulation of bull trout associated with the four lower Snake River reservoirs spawn and rear in the Tucannon River basin. Both resident and migratory forms occur here. Only resident fish are present in the headwater of Pataha Creek, but both forms exist in the mainstem Tucannon River and its upper tributaries (WDFW, 1997). Evidence suggests that migratory bull trout from the Tucannon River also utilize the mainstem Snake River on a seasonal basis (Buchanan et al., 1997 citing Ward; WDFW, 1997). Kleist (1993) reported several observations of adult bull trout passing Lower Monumental and Little Goose dams. From 1994 to 1996, there were 27 bull trout passing the adult fish counting station (mainly in April and May) at Little Goose Dam (S. Richards, WDFW, fishery biologist, personal communication). At least six bull trout passed counters at Lower Monumental and Little Goose dams in 1991 and 1992 (Kleist, 1993). Kleist also observed one bull trout in 1993 just downstream of the count window at Lower Monumental Dam. Furthermore, one bull trout was captured in the Palouse River below Palouse Falls in 1998 (G. Mendel, WDFW, fishery biologist, personal communication). These were likely migratory fish from the Tucannon

River. However, one bull trout was observed at Lower Granite dam in 1998 (D. Hurson, Corps. fishery biologist, personal communication) that may indicate fluvial fish are migrating to other upstream populations.

The status of bull trout associated with the Tucannon River was rated as "healthy" by WDFW, although some habitat degradation has occurred due to timber harvest and recreational use. It is not currently at risk of extinction, and is not likely to become so in the foreseeable future because of sufficient habitat protection (wilderness designation) in the upper watershed and the lack of brook trout encroachment from Pataha Creek. The Pataha Creek subpopulation is at risk of extinction as a result of habitat degradation and competition and hybridization from brook trout.

Water howellia (*Howellia aquatilis*)—This annual aquatic plant was listed as a threatened species in 1994. It has small inconspicuous flowers that grow beneath the water surface and small white flowers that form above the water surface. It grows in two general types of wetland/riparian habitats: (1) small isolated ponds (also known as vernal or seasonal ponds) and (2) river oxbows that may be abandoned or hydrologically linked to the adjacent river system. There is one known location in Idaho about 81 km (50 miles) north of the study area. Threats to this species are from loss of wetland habitat and habitat changes from timber harvesting, livestock grazing, residential development, and competition by exotic plant species. Other activities that may impact the hydrology of its habitat may also adversely impact this species. Surveys for water howellia should be conducted from June through August if proposed facilities may involve riparian (especially oxbow) or seasonal pond habitats.

McFarlane's four-o'clock (*Mirabilis macfarlanei*)—Listed as endangered in 1979, this plant was downlisted to threatened in 1996. It is known only from sites on the lower Snake, Salmon, and Imnaha rivers, all upstream about 48 km (30 miles) from the study area. It occurs in grassland habitat from flats to steep slopes and from sandy soils to rock talus. Its primary habitat is bunchgrass communities dominated by bluebunch wheatgrass. Exotic plant species, particularly, cheatgrass and yellow star-thistle, pose a serious threat to McFarlane's four-o'clock.

Ute ladies'-tresses (*Spiranthes diluvialis*)—This perennial orchid was listed as threatened in 1992. It was only discovered in southeastern Idaho in 1996 along the upper Snake River and in 1997 in northern Washington. Surveys for this plant have not been conducted within the study area. It is found in wetland and riparian areas, including spring habitats, mesic to wet meadows, river meanders, and floodplains. This species may be adversely affected by modifications of its habitat associated with livestock grazing, vegetation removal, excavation, construction activities, stream channelization, and other actions that alter hydrology or vegetative cover.

5.4.2.13 Other Species Of Concern

Wildlife

Black tern (*Chlidonias niger*)—Black terns are small terns that eat primarily insects and can occur statewide, in or near wetlands and sloughs. They usually nest in marshy wetlands in June; however, they would probably be in the study area only during migration.

California floater—These mussels are found in unpolluted fresh water, except small creeks. They prefer lakes and slow streams with areas less than 2 m (6.6 feet) deep and sandy bottoms. Adults will also live on mud bottoms. Juveniles are parasitic on gills, fins, and barbels of host fish.

Columbia pebblesnail (*Fluminicola [=Lithoglyphus] columbianus* [Hemphill in Pilsbry, 1899]) (great Columbia River spire snail)—These snails are found in the main channels and free-flowing parts of rivers such as the Columbia, Grand Ronde, Salmon, and Snake rivers. More recent documentation indicates they are present just above the study area on the lower Snake River. They are often common at the edges of rapids or immediately downstream of whitewater areas, and, they feed on diatoms and algae.

Columbia spotted frog (*Rana pretiosa*)—Columbia spotted frogs are found in warmwater marshes, overflow wetlands, and bogs with non-woody wetland vegetation. They are found scattered across most of eastern Washington.

Ferruginous hawk (*Buteo regalis*)—These large hawks prefer open plains and brushy open country and avoid forested areas. They nest in trees along streams, bluffs, rock piles and artificial structures. Ferruginous hawks feed primarily on ground squirrels, rabbits and other small mammals.

- Other species include the following:
- Fringed myotis (*Myotis thysanodes*)
- Long-eared myotis (*Myotis evotis*)
- Long-legged myotis (*Myotis volans*)
- Pale Townsend's (= western) big-eared bat (*Plecotus townsendii pallescens*)
- Small-footed myotis (*Myotis ciliolabrum*)
- Yuma myotis (*Myotis yumanensis*)—Information on these species is found in earlier sections.

Harlequin duck (*Histrionicus histrionicus*)—Harlequin ducks generally rely on fast, turbulent mountain streams as breeding habitat. They would be present in the study area in August and September, following the nesting season.

Little willow flycatcher (*Empidonax traillii brewsteri*)—This flycatcher uses open brushy areas, especially scrub-shrub wetlands comprised of willow.

Loggerhead shrike (*Lanius ludovicianus*)—Loggerhead shrikes are robin-sized birds which feed mainly on insects, with small birds and mammals taken in winter. Preferred habitat includes shrub-steppe and any semi-open area with shrubs, fences, powerlines, or small trees for perches.

Margined sculpin (*Cottus marginatus*)—The former range of these sculpins are unknown; however, they currently inhabit the Walla Walla and Tucannon rivers in Washington. They are a benthic species whose requirements are poorly known. However, without competition, they seem to prefer cool (55 to 66°F) water, moderate to rapid current, and rubble or gravel substrate. Margined sculpins spawn in the spring.

Mountain quail (*Oreortyx pictus*)—These uncommon birds prefer shrubby/forested areas and are found at lower elevations in the Blue Mountains.

Northern goshawk (*Accipiter gentilis*)—These large hawks prefer mature and old-growth forests for nesting and would not nest in the study area. Observations of goshawks would likely be during migration and winter. They are aerial hunters, flying between trees and under canopy in search of grouse, smaller birds, and other prey.

Northern sagebrush lizard (*Sceloporus graciosus graciosus*)—These lizards are primarily shrub-steppe dwellers, but also use bouldered regions and forested slopes. They are typically ground lizards and rarely climb into shrubs. They prefer fine gravel soils, but are also found on sandy or rocky soil. They need rock crevices, mammal holes, and similar cover for refuge.

Olive-sided flycatcher (*Contopus borealis*)—These birds seem to prefer mixed and broken forests with wooded streams and some wetland. Their diet consists entirely of flying insects which they search for from high snags and perches. They nest high in conifer trees.

Pacific lamprey (*Lampetra tridentata*)— These fish have spawning habitat requirements similar to those of salmonids, including clean gravel and cold water. They spend about 5 years as ammocoetes, blind filter feeders that burrow in mud and fine sediments in pools, quiet backwaters, and eddies, downstream from spawning riffles. The ammocoetes migrate slowly downstream, with their movement apparently triggered by high water flow. Between 4 and 6 years, ammocoetes start metamorphosing into adults and become parasitic on soft scaled fish. The adults migrate to sea, where they remain until they return to spawn and die.

Washington ground squirrel (*Spermophilus washingtoni*)—These squirrels are found in steppe and open shrub-steppe, where they prefer deep, loose soil for digging burrows. One existing colony in Walla Walla County is within the study area, while five additional colonies are located nearby.

Western burrowing owl (*Athene cunicularia hypugea*)—These owls are generally found in open, broken, or flat areas, including shrub-steppe and agricultural areas. Opportunistic feeders, they prey primarily on insects and small mammals, but also on birds, fish, and amphibians, when available. They use ground squirrel or other mammal burrows for shelter and nesting.

Plants

Northwest raspberry (*Rubus nigerrimus*)—This is a Snake River endemic that is found in the Snake River canyon and adjacent tributaries (Washington Natural Heritage Program [WNHP], 1981). It occurs along drainage bottoms and somewhat moist areas on the adjacent slopes along small tributaries to the Snake River, such as Nisqually John Canyon. It is known from less than two dozen sites, with some of the historic sites inundated with the construction of Lower Granite Dam (Clegg, 1973). Whether it has become established along the current reservoir shorelines is unknown; however, it has become established on at least four of the intensive HMUs (Phillips, 1993).

Jessica's aster (*Aster jessicae*)—This tall perennial species has blue flowers and can be found in association with the northwest raspberry. It is found along streambanks and open places in the Palouse region and is currently known from only nine populations in Whitman County (WNHP, 1981).

Broad-fruit mariposa (*Calochortus nitidus*)—This very showy species has purple flowers and is found along the borders of seasonally wet meadows (WNHP, 1981). Although there is no documented presence within the study area, it has been found in Garfield and Whitman counties.

Spalding's silene (*Silene spaldingii*)—Although not documented within the study area, this species has been found in Whitman and Asotin counties. This plant has white flowers and is found in virgin Idaho fescue (*Festuca idahoensis*) habitat types in the Palouse region (WNHP, 1981).

Washington polemonium (*Polemonium pectinatum*)—A member of the phlox family, this species has white or creamy flowers and has a characteristic skunk smell. Its habitat includes moist bottomlands and has been found in Whitman County.

6. Future With Existing Systems Alternative

6.1 Anadromous Fish (with Existing Systems Alternative)

6.1.1 Effects of Existing Operations on Anadromous Salmonids

Construction and operation of the lower Snake River dam and reservoir system have affected anadromous salmonids in several ways. These include inundation of spawning habitat, changes in migration rates and conditions of juvenile fish through the reservoirs and at the dams, changes in adult migration conditions, and improved habitat for predators of juvenile salmonids. The PATH group (1996) has concluded the following:

> *We are reasonably confident that the aggregate effects of the hydrosystem have contributed to reduced survival rates of Snake River stocks (from spawners to adults returning to the mouth of the Columbia River), during the post-1974 period, as compared to the pre-1970 period. Hydrosystem effects include both direct (e.g., turbine morality) and indirect effects (e.g., delayed mortality, due to such mechanisms as changes in estuary arrival times).*

The lower Snake River dams have created reservoirs which affect juvenile salmonid migration by reducing water velocity and disrupting migration timing (Raymond, 1979). Higher water temperatures, decreased turbidity, and increased predator populations in reservoirs, combined with increased passage time through these bodies of water, have resulted in greater mortality of juvenile salmonids during downstream passage. Salmonids that cannot migrate during the critical smolt period may remain in the reservoirs and revert to a freshwater form.

This delay has affected all juvenile salmon and steelhead migrants, including those that migrate during the spring and those that move downstream in the summer. The life history of Snake River fall chinook salmon may make them more susceptible to delays in migration than other anadromous salmonids (Venditti, et al., 1998). Snake River fall chinook display an ocean type of life history in that they migrate to the ocean as subyearlings. Fall chinook outmigration occurs later than the main seaward migration of spring/summer chinook and steelhead. This exposes them to lower river flows, increased water temperatures, and greater predation. Fall chinook typically pass Lower Granite Dam from June through October; yearling spring/summer chinook pass Lower Granite Dam from early April to mid-June; steelhead pass from early April to early June; and wild sockeye from late March through early July.

The PATH group has examined juvenile salmon survival in the Snake River system and concluded that "the hydrosystem has contributed to decreased juvenile survival in the downstream corridor for Snake River stocks in the post-1974 period." This conclusion was based on a comparison of survival of juvenile fish from the area of the head of Lower Granite Reservoir to Ice Harbor Reservoir for the 1964 to 1966, 1974 to 1982, and 1991 to 1994 brood years.

Under the Existing Systems Alternative, physical reservoir conditions would not change to any extent. Water velocities and water temperatures in all of the reservoirs would remain similar to those that now exist, unless additional flow augmentation and water temperature control are provided. Fish migration rates and behavior in the reservoirs would not differ significantly from those that have been observed previously and would depend on the volume of river flow. Migration rates would decrease from spring to summer as the volume of river flow diminished. The movement of subyearling fall

chinook salmon through the lower Snake River system would decrease as they moved downstream in each reservoir, with the slowest migration and greatest delay occurring in the forebay. Sockeye salmon, which migrate downstream during part of the subyearling fall chinook migration period, would experience similar conditions of decreasing streamflow and increasing water temperatures. Yearling steelhead and spring/summer chinook salmon, which migrate earlier when streamflow is higher and water temperatures are lower, would experience similar conditions to those that have occurred under the NMFS 1995 Biological Opinion.

Under the Existing Systems Alternative, the lower Snake River dams would remain in place and continue to operate without major change. Some structural changes would be made to improve conditions for migrating adult and juvenile salmonids. Effects on anadromous fish are expected to be similar to those now experienced by all species and runs of fish. Juvenile salmonids would continue to be collected and transported to the lower Columbia River for release or would remain in the river to migrate after passing the dams via spill, collection, and bypass to the river, or through the turbines. To date, neither the juvenile fish transportation program nor the present inriver migration conditions that currently exist have been able to stop the decline of wild Snake River spring and summer chinook salmon. Juvenile salmonids would continue to be delayed in the dam forebays and would suffer continued losses. Fish would be delayed most during low flow periods or when no spill occurred. This is the time when collection and transportation would be most desired. The planned improvements to the existing dam system, such as extended length screens and spill deflectors, that result in greater fish passage efficiency may increase the survival of juvenile fish. The Corps has committed over $20 million to upgrade the juvenile fish collection /bypass system at Lower Granite Dam. However, juvenile fish would continue to be affected by reservoir conditions which delay migration, increase predation, and subject them to adverse water temperatures, unless adequate flows are provided during the migration season. Juvenile salmonids would continue to be impacted by the extremely high levels of TDG when uncontrolled spill conditions exceed the gas reducing capability of the spill deflectors.

Conditions at the main ladder entrances would continue to be improved to enhance the upstream passage of adult salmonids. For example, the auxiliary water supply at Ice Harbor and Lower Granite dams would be improved to attract adult salmonids to the fishway entrances. Losses of adult salmonids that now occur during passage at the four lower Snake River dams would continue at their present rates. Passage delay would occur at each dam, especially during high flow years when fish have difficulty finding fish ladder entrances. High flows and uncontrolled spills would likely cause adult fish to fall back over the dams after exiting the ladders and would also subject them to high levels of TDG during periods of involuntary spill. Adult salmonids have also exhibited "head burns," a condition in which the head appears raw or blistered and which may cause increased mortality before spawning. The cause of headburns is unknown, but is suspected to be dam related. This situation would continue to occur until its cause is determined and removed.

6.1.1.1 Inundation of Spawning Habitat

The reservoirs in the lower Snake River have inundated about 225 km (140 miles) of free flowing river which formerly provided spawning habitat for fall chinook salmon. Limited fall chinook spawning now occurs in the tailraces of Lower Granite and Little Goose dams near the juvenile fish bypass outfalls. Spawning may also occur in the tailrace of Lower Monumental Dam. Under the Existing Systems Alternative the lower Snake River reservoirs would remain in place, and former spawning habitat would continue to be inundated. The limited fall chinook salmon spawning that now occurs in the dam tailraces would continue.

6.1.1.2 Changes in Migration Rates of Juvenile Fish

Development of the dam and reservoir system in the Snake River Basin has changed the hydrograph and migration corridor in the lower Snake River. Construction of the lower Snake River dams has changed this stream from a free-flowing system into a series of slack water reservoirs. In addition, storage reservoirs in the upper Snake River Basin have reduced peak flows that occur in the spring and early summer. Reservoirs now capture and store water for irrigation or for later release for power generation during fall and winter months.

The reservoirs have also altered the cross-sectional area of the migration corridor in the lower Snake River. The lower Snake River from Ice Harbor Dam to the head of Lower Granite Reservoir has been changed from its former narrow channel to wider and deeper reservoirs. This has slowed water velocity in this reach of river and increased the time required for water to travel through the reservoirs compared to a free-flowing system. Lowered water velocities in the reservoirs have slowed migration rate of juvenile salmonids through the Snake River (Sims and Ossiander, 1981).

Survival of juvenile salmonid migrants has been shown to be related to travel time through the Snake River, and total travel time is inversely related to river flow. Juvenile salmonid survival may be affected by low flows and increased travel time in several ways. These include 1) increased likelihood of residualism (that is, failure to migrate) in reservoirs, 2) reduced ability to tolerate salt water, 3) delayed entry into the estuary and ocean after the time when optimum conditions exist, 4) increased exposure time to predators during migration, 5) exposure to higher water temperatures (Columbia Basin Fish and Wildlife Authority [CBFWA], 1991), and 6) delayed mortality caused by stress incurred during passage through the hydrosystem.

Migrating juvenile salmon and steelhead smolts rely primarily on passive transport by water currents and generally do not actively swim downstream. Their successful downstream migration depends on river flow and water velocity which determine how fast they move through the Snake and Columbia rivers to the estuary. Anadromous salmonid smolts are physiologically able to make the transition from freshwater to saltwater during a limited period of time and must reach the estuary within this period. Delays in the downstream migration of juvenile salmonids may affect their ability to successfully make this transition. Delays in migration can subject smolts to higher temperatures. In addition, delayed migration through slow-moving water in reservoirs likely leads to increased predation by fish such as northern pikeminnow and smallmouth bass which become more active at higher water temperatures.

The anadromous fish of the Snake River System historically used the increasing flows of the spring and early summer freshet and migrated seaward during this period. Mains and Smith (1964) found that the major period of downstream migration by chinook salmon occurred in the spring and corresponded to the spring freshet during sampling in 1954 and 1955. They noted that downstream movements of chinook fingerlings appeared to be influenced by increases in flow. They also indicated that while temperatures may have played a role in starting the downstream migration of chinook salmon, the first spring freshet was the main factor responsible for stimulating downstream migration. The Snake River discharge required to begin chinook salmon migration was about 70,000 cubic feet per second (cfs) in both years.

Before the Snake River dams were built, smolts took 22 days to travel from the Salmon River in Idaho to the Columbia River downstream of Bonneville Dam (Ebel, 1977). Since construction of the Snake River dams, the migration time from the Salmon River to the lower Columbia River has increased to as much as 50 days (Ebel, 1977).

The travel time and survival of spring/summer chinook salmon smolts through the Snake River is related to river flow and water velocity. Sims and Ossiander (1981) estimated smolt travel time and survival from 1973 to 1978. They found that travel times for chinook salmon and steelhead were related to river flow and that faster migrations occurred during years of higher river flows. They also found a positive correlation between the average smolt survival at the each of the Snake River dams and flows at Ice Harbor Dam during the period of peak migration.

Raymond (1979) also found that the survival of Snake River smolts was much lower in years when flows and spills were low than in years of higher flows and spills. Raymond (1988) also examined the survival rates of return of adult chinook and steelhead to the Snake River and concluded that the juvenile-to-adult survival rates of fish that had migrated out from 1962 to 1964 had declined because of hydroelectric development.

Petrosky (1991) examined smolt-to-adult survival rates for Rapid River hatchery and Marsh Creek wild populations of Snake River spring chinook from 1977 to 1987 and compared them with flows at Lower Granite Dam. Petrosky found a positive relationship between migration flows during smolt outmigration and the return rates of these fish which tended to substantiate the flow and smolt survival relationship of Sims and Ossiander (1981).

Delay also occurs when juvenile salmonids approach and pass dams. Migration rates of subyearling fall chinook salmon through the lower Snake River reservoirs appear to decrease as they approach the dams. Venditti et al. (1998) found that the median migration rates of radiotagged juvenile fall chinook salmon decreased from more than 20 km (12.4 miles) per day in upper Little Goose Reservoir to between 10 and 15 km (6.2 and 9.3 miles) per day in the middle reservoir to about 1 km (0.6 mile) per day in the lower reservoir or forebay during studies conducted in 1995, 1996, and 1997. They also found that 10 to 20 percent of these fish spent more than a week in the forebay. The decreased migration rate was attributed to declining water velocities the fish encountered as they approached the dam. The delayed fish displayed two patterns of movement: one involved repeated crossings of the forebay; the other involved fish moving back upstream as far as 14 km (9 miles) after first entering the forebay. The additional delay in migration displayed by up to 20 percent of the subyearling fall chinook could subject them to additional predation losses and high water temperatures at each dam that these fish pass.

With the Existing Systems Alternative, juvenile fish migration rates and survival would not change appreciably unless greater water velocity were provided in the lower Snake River reservoirs, and passage delays at the dams could be reduced. Increased water velocity would require either additional flow in the Snake River or a reduced cross-sectional area in the river migration corridor. The optimum water velocity regime would be one that simulated the velocities that occurred in the lower Snake River during juvenile fish migration periods before the dams were built.

6.1.1.3 Adult Fish Migration

The lower Snake River dams and reservoirs have changed migration conditions for adult salmon and steelhead. Anadromous fish now face an altered system that involves entry into fishways, passage through fish ladders and reservoirs, and altered flow and temperature regimes.

The cumulative loss of adult salmonids as they pass the eight dams and reservoirs in the lower Columbia and Snake rivers can be significant. Adult fish losses can be caused by delayed migration, fallback through turbines, and delayed mortality caused by marine mammal predation injuries, gillnet interactions, and disease (NMFS, 1995b). Based on an analysis of radiotagging studies, NMFS

estimates that about 39.3 percent of the adult fall chinook, 20.9 percent of the spring/summer chinook, and 15.4 percent of the sockeye are lost during passage through the eight dam and reservoir projects in the lower Columbia and Snake rivers (NMFS, 1995b).

The PATH group has analyzed adult fish loss in the lower Snake River by examining the difference in counts of adult fall chinook at the dams. This count is adjusted for legal harvest, but is complicated by counting errors at the dams, recounting of fish that fall back past the dams and later reascend the ladders, straying, tributary turnoff, and fish spawning in dam tailraces. This analysis indicates that the percentage of adult fall chinook counted at Lower Granite Dam that were also counted at Lower Monumental Dam ranged from 37 to 100 percent for the period from 1975 to 1996 and averaged 73 percent.

Adult passage can be delayed at the Snake River dams. The average delay for spring/summer chinook salmon at each lower Snake River facility was found to be 1 to 3 days when no spill was occurring and 5 to 7 days during high spill (Turner et al., 1983, 1984 in NMFS, 1995b). During 1993, the median delay was from 0.6 to 1.2 days during periods of no spill to spill of 3.2 m^3 to 6.4 m^3 (40 to 80 thousand cubic feet per second [kcfs]) (Bjornn, et al., 1994 in NMFS, 1995b).

The total passage times through the lower Snake River for adult spring and summer chinook salmon are not believed to have increased since the construction of the four Corps of Engineers dams. Bjornn et al. (1998) reported that the overall time for radiotagged spring/summer chinook salmon to migrate through the lower Snake River (about 6.4 days) was comparable to that of pre-dam conditions. Upstream migrants were slowed at dams, but migrated through reservoirs at a faster rate than through free-flowing rivers.

Adult salmonids that pass the lower Snake River dams may fall back over the spillways, through the turbines, down the fishways, or through the navigation locks. Fallback has been documented in studies at all of the lower Snake River dams and has ranged from about 4 to 40 percent during studies (Bjornn and Peery, 1992). Radiotracking studies indicate that salmon that fell back over one or more dams were less likely to complete their migrations to hatcheries or to the spawning grounds than fish that did not fall back (Bjornn et al., 1998). Some of the fish that fall back may also have strayed into the Snake River from other areas such as the Hanford Reach of the Columbia River. Those fish may fall back past the dams to reach their proper spawning areas.

Large volumes of spill during conditions of involuntary spill can delay the upstream migration of adult salmonids by making fish ladder entrances difficult to locate. Adult passage counts at the lower Snake River dams typically are reduced when flows are high and uncontrolled spill occurs. However, voluntary spill that is provided to improve juvenile fish passage does not appear to affect upstream migrating adult salmon. Bjornn et al. (1998) reported that nighttime spilling for juvenile fish passage at Ice Harbor and Lower Monumental dams resulted in adult passage rates that were similar to those at Little Goose Dam where spill was not provided. Voluntary spills proposed in the NMFS 1998 Supplemental Biological Opinion are not expected to adversely affect adult salmonid passage at any of the lower Snake River dams based on preliminary information from radiotracking studies conducted by University of Idaho staff (NMFS, 1998b).

A limited number of fall chinook salmon presently spawn in the tailraces of some lower Snake River dams. Salmon embryos were observed when a site was dredged at Lower Monumental Dam in 1992 (Dauble et al., 1994). However, salmon redds have not been found during surveys that were made in following years. Fall chinook salmon redds have been observed downstream from Lower Granite and Little Goose dams. Spawning presently occurs in limited areas near the juvenile fish bypass outfalls

at both dams (Dauble et al., 1995). Fall chinook salmon would continue to spawn downstream from Lower Granite and Little Goose dams and possibly Lower Monumental Dam with continued operation of the lower Snake River dams.

Concerns have also been raised about the effect high water temperatures in fish ladders have on the migration and survival of adult salmonids. Water temperatures are often higher than 20°C (68°F) and have the potential to delay adult fish migration or to increase the mortalities of adult chinook salmon and steelhead (Bjornn et al., 1997). Water temperatures in the fish ladders have been monitored in the fishways and forebays of Lower Granite and Little Goose dams to see if there is a need to control temperatures. Fish will be examined to determine the relationship between high water temperatures and fish passage at dams.

Under the Existing Systems Alternative, conditions for adult salmonid migration would not change significantly. Adult salmonids would continue to pass the lower Snake River facilities at their present rates and would experience similar mortality and injury rates. Current structural and operational changes at the dams and reservoirs made to improve conditions for adult fish passage would continue. For example, a concrete training wall is proposed for construction at Ice Harbor Dam to improve fish ladder entrance conditions. This modification was recommended to offset the effects of changes in current patterns that resulted from the installation of flow deflectors to reduce TDG.

6.1.2 Present Facility Operations

6.1.2.1 Spill

Two types of spill, involuntary and voluntary, can take place at the lower Snake River dams. Involuntary spill occurs when high river flow exceeds the hydraulic capacity of the dam's turbines or when a lack of electrical power demand reduces the volume of water passing through the turbines. Voluntary spill is provided for juvenile fish passage. It is a controlled operation which can be started or stopped at any time.

The NMFS 1995 Biological Opinion specifies that water be spilled at the lower Snake River dams to increase the fish passage efficiency and survival of juvenile salmonids when they pass the dams. Fish passage efficiency is the percentage of juvenile salmonid migrants that pass a dam by routes other than turbines. These routes can include spillways, mechanical collection and bypass systems, fish ladders which have been converted to juvenile bypass structures, and navigation locks.

Previous studies at Columbia and Snake river dams have shown that juvenile salmonids survive spillway passage at a higher rate than passage through turbines. Studies have shown that mortalities of juvenile salmonids passing through turbines have ranged between 8 and 32 percent while the mortality rate of fish passing via spillways was between 0 and 4 percent (CBFWA, 1995). The mechanical collection systems at the lower Snake River dams cannot divert all of the migrating juvenile salmonids away from turbine intakes and into fish bypass systems. Passage through the mechanical collection and bypass system can also result in injury and mortality to juvenile migrant salmonids. However, the survival benefits of transportation are assumed to outweigh the negative effects of collection and transportation. Additional mortality due to increased predation by birds or fish can also occur at bypass outfalls. Fisheries agencies have, therefore, recommended spilling to improve the overall survival of juvenile salmonids passing mainstem Columbia River dams and the lower Snake River dams. Controlled spill programs have been in effect since 1983 at the mid-Columbia River dams operated by the Chelan, Grant, and Douglas county public utility districts and since 1989 at some Corps' dams (CBFWA, 1995).

The NMFS 1998 Supplemental Biological Opinion specifies that spilling is to occur at the lower Snake River dams during the spring and summer juvenile fish migration seasons. The planning dates for spill are April 3 to June 20 for the spring season and June 21 through August 31 for the summer season. Voluntary spill would occur when the seasonal average forecasted flows at Lower Granite Dam are projected to exceed 85 kcfs during the spring migration period. During the juvenile fall chinook salmon migration period (June 21 to August 31), spilling is recommended only at Ice Harbor Dam.

Spilling of water can cause supersaturation or increased levels of TDG downstream from the dams. High TDG levels can create bubbles in the bodies of fish and other aquatic organisms when the gases come out of solution. This may cause injury or death to fish and other aquatic life at high levels. State of Washington water quality standards limit TDG levels in the Snake River to 110 percent. However, the Washington Department of Ecology (WDOE) issued waivers of the standard in 1995, 1996, 1997, and 1998 to NMFS to allow TDG levels of up to 120 percent in the tailraces and 115 percent in the forebays of the lower Snake River projects. Biological and physical monitoring has been required as a condition of the waivers. In addition, WDOE required that a TDG management plan be developed as a condition for issuance of the TDG waiver in 1998.

There has been controversy about the use of spill for juvenile fish migration. Some parties believe that the levels of spill and TDG allowed by the NMFS spill program are too high for juvenile fish and may expose adult fish to high gas levels for longer periods of time. Others believe that spill volumes and TDG could be higher and that spill should continue at all Snake River dams throughout the summer migration season.

In general, studies and biological monitoring that have been conducted show that juvenile and adult salmonids and resident fish are not adversely affected by TDG levels below 120 percent. Biological monitoring has documented the effects of exposure to varying levels of TDG upon juvenile and adult salmonids and other fish. In 1995, when the 120 percent TDG limit was exceeded very few times, and 130 percent TDG was exceeded only at Ice Harbor Dam, the incidence of gas bubble trauma (GBT) in juvenile fish was very low and none exhibited severe signs of GBT. In 1996, the 120 percent TDG level was exceeded 357 times, and the 130 percent level was exceeded 113 times primarily as a result of involuntary spill caused by high runoff. Severe signs of GBT were observed in 0.12 percent of the juvenile fish examined. Extremely high flows in the Columbia River in 1997 again resulted in involuntary spill and extended periods of high TDG levels greater than 120 and 130 percent. In 1997, TDG levels exceeding 120 percent were recorded 350 times, and levels higher than 130 percent were recorded 162 times. Severe signs of GBT were seen in 0.27 percent of the juvenile salmonids that were examined (NMFS, 1998a).

About 0.1 percent of 6,312 adult chinook salmon that were examined at Lower Granite Dam in 1997 exhibited signs of GBT. However, sockeye salmon and steelhead that were examined at Bonneville Dam showed higher incidences of GBT than chinook salmon at that site. Highest incidences of GBT were noted during the first half of June when involuntary spill and flow were at their maximums (NMFS, 1998a). Data from the monitoring stations at Skamania, Washington and Warrendale, Oregon indicate that average TDG levels remained higher than 129 percent throughout the first half of June, 1997. The minimum TDG reading at these stations during this time was more than 127 percent.

Based on the results of the biological monitoring program it appears that the TDG levels of 120 percent in the tailraces and 115 percent in the forebays as authorized in the waivers issued by WDOE, do not threaten the survival of migrating salmonids.

NMFS has recommended continuation of a spill program with modifications in its 1998 Supplemental Biological Opinion. NMFS has recommended that spill should be maximized to the gas cap limits at the lower Snake River facilities with the actual dates of spill to be determined each year by the Technical Management Team (TMT) based upon in-season monitoring information. Spill volumes and hours of spill at each of the lower Snake River facilities are shown in Table 6-1.

Table 6-1. Spill Cap Volumes, and Hours of Spill at Lower Snake River Dams under the NMFS 1998 Biological Opinion

Facility	Spill Volume (kcfs)	Limiting Factor	Hours of Spill
Lower Granite	45	Gas Cap	6 p.m.-6 a.m.
Little Goose	60	Gas Cap	6 p.m.-6 a.m.
Lower Monumental	40	Gas Cap	6 p.m.-6 a.m.
Ice Harbor	75 (night) 45 (day)	Night—Gas Cap Day—Adult Fish Passage	24 hours

Under the Existing Systems Alternative, the lower Snake River dams would remain in place, and the voluntary spill program would continue. Involuntary spill would occur whenever river flow exceeded dam powerhouse capacity or when there was a lack of a market for electrical power. Spill deflectors (flip lips) would be installed at all the dams and would help maintain lower TDG levels at higher volumes of spill. However, TDG levels would not be controllable when river discharge exceeded the total capacity of the spill deflectors and powerhouses until the Corps' Dissolved Gas Abatement Program was implemented. Under those conditions, TDG concentrations would exceed state water quality standards of 110 percent or the waiver levels of 120 percent. Juvenile fish mortality would increase at higher levels of spill and TDG, especially when TDG levels were greater than 130 percent.

Involuntary spill usually occurs during the spring and early summer runoff and would have the greatest effect on spring migrants. These would include juvenile steelhead, spring and summer chinook, sockeye, and coho. Summer migrants, such as subyearling fall chinook, would be less affected by high flows and involuntary spill.

Adult steelhead which overwinter in the Snake River, and spring and summer chinook and sockeye salmon could be present when spill occurs. Based on adult fish monitoring results to date, chinook salmon would not be greatly affected by high TDG levels. Sockeye salmon and steelhead would be more affected than chinook when TDG levels were high based on the results of sampling conducted at Bonneville Dam in 1997.

Long-term measures to reduce TDG levels are being investigated by the Corps through its Dissolved Gas Abatement Study. The Corps has identified several alternative measures that have the potential to reduce TDG. These include spillway deflectors with raised tailraces, raised stilling basins with raised tailraces, raised stilling basins, spillway deflectors, raised tailraces, submerged spill discharges, submerged discharges with deflected spill, raised stilling basins with deflectors, additional spillway

bays, side channels, and raised stilling basins with raised tailraces and deflectors (Corps 1997a; Northwest Hydraulic Consultants, 1998).

The Dissolved Gas Abatement Study is presently scheduled for completion in September of 1999 or 2001, depending on the extent of biological research conducted. Implementation of any of the feasible gas abatement alternatives would require additional study and development of final designs. This process would require an additional three years before the implementation process could begin.

6.1.2.2 Flow Augmentation

Reduced flow velocity through the reservoirs is believed to have contributed to the decline of Snake River salmon (NMFS, 1995a). Slow passage of water through the reservoirs prolongs the migration time of juvenile salmonids through the lower Snake River System. This increases their time of exposure to predators and to higher temperatures. Higher temperatures can increase predation rates upon juvenile salmonids and make them more susceptible to disease.

The effect of streamflow in the Snake River on the rate of juvenile salmonid migration and survival has been examined by several investigators. Increased streamflows can reduce the travel time of steelhead smolts and both yearling and subyearling chinook salmon (Berggren and Filardo, 1993). Giorgi et al. (1997) reviewed flow augmentation from 1991 to 1995 and found that flow augmentation during those years could substantially decrease water particle travel time in Lower Granite Reservoir in the summer when natural runoff is low.

Beuttner and Brimmer (1996) found a significant relationship between migration rates of juvenile chinook salmon and steelhead and increases in river discharge in the Snake River. Detections of PIT-tagged fish showed increased migration rates for hatchery and wild chinook salmon and hatchery and wild steelhead from the Snake and Salmon rivers to Lower Granite Dam with increases in river discharge. Their results for 1995 studies showed that a twofold increase in river discharge from 50,000 to 100,000 cfs resulted in a twelvefold increase in the migration rate of hatchery chinook salmon through Lower Granite Reservoir. Wild chinook migration rates were increased by 4.6, hatchery steelhead by 2.1, and wild steelhead by 2.4 times.

Smith et al. (1997a) found a strong and consistent relationship between flow levels and travel times for chinook salmon and steelhead where higher flows were associated with shorter travel times. They also noted an increase in the survival of yearling chinook salmon and steelhead in study reaches upstream from Lower Monumental Dam. Survival for both species was higher in 1996 than in previous years. This was attributed in part to higher flows.

Increased flow in the Snake River should reduce predation on juvenile salmonids during their outmigration through the reservoirs. Bennett, et al. (1996) reported that substantial variation in predation on subyearling chinook salmon in Lower Granite Reservoir occurred from year to year. Higher predation was noted during low flow years when water temperatures were higher and water clarity was greater. They noted the importance of flow augmentation during low flow years to maintain higher flows through Lower Granite Reservoir during June and July. An analysis of PIT tag interrogations showed higher numbers of tagged fish were detected at Lower Granite Dam during high flow years. They indicated that possible benefits of increased flow included lower predation rates and improved migration through Lower Granite Reservoir.

Flow augmentation is provided under requirements of the NMFS 1995 Biological Opinion and 1998 Supplemental Biological Opinion. This is accomplished by drafting Dworshak Reservoir down to

463 m (1,520 feet) in elevation through August 31, by the BOR providing 427 thousand acre-feet of flow augmentation from the upper Snake River, and by having Idaho Power Company provide stored water from Brownlee Reservoir to help meet flow objectives at Lower Granite Dam. These actions are presently the main measures used to augment flows in the lower Snake River.

Flow objectives at Lower Granite Dam have been established on a sliding scale for the spring and summer. The spring flow objective ranges between 85 and 100 kcfs on a linear sliding scale when the April to July water volume runoff forecast for the Snake River at Lower Granite Dam is between 16 and 28 MAF. The flow objective is for at least 100 kcfs when the volume runoff forecast is more than 28 MAF.

The summer flow objective is determined similarly. When the April to July volume runoff forecast is between 16 and 28 MAF, then the summer flow target is between 50 and 55 kcfs. When the forecast is greater than 28 MAF, then the summer flow target is at least 55 kcfs.

The TMT, which is composed of representatives of fishery management agencies and the Federal dam management and power marketing agencies, addresses flow augmentation requirements during the fish migration season. The TMT makes weekly flow recommendations for the Columbia and Snake River dam and reservoir system based on considerations for the following: (1) the timing and number of fish migrating; (2) the probability that enough water will be available to augment flows for juvenile and adult fish throughout the migration season, or that in low water years available water will be allocated according to designated priorities among different species and life stages; and (3) instream water temperatures and the effect augmentation would have on future temperature conditions and fish resources.

The Snake River System reservoirs and streamflows have been managed for 3 years under the NMFS 1995 Biological Opinion's requirements for fish passage. In 1995, the seasonal flow targets were met for both the spring and summer. Daily flows were lower than the spring target during April and early May and lower than the summer target after mid-July. The years 1996 and 1997 were high runoff years in the Snake River Basin, which should have provided ample supplies of water for flow augmentation. In 1996, the Snake River storage reservoirs were operated to meet flood control requirements during the spring and early summer, and spring flows were the result of flood control operations. The spring flow target at Lower Granite Dam was exceeded. The summer flow target was met on a seasonal basis, but flows varied during this period and were below the target at times (FPC, 1997).

In 1997, the spring weekly flow target was met at Lower Granite Dam. The summer seasonal flow target was met, but the weekly flow targets were not met during August because of an inability to obtain additional flow from Brownlee Reservoir. In this case, the additional flow from Brownlee Dam would have caused spill and lost power generation at the Idaho Power Company's Hells Canyon Dam. The Idaho Power Company requested compensation from the BPA for this loss. The BPA declined to reimburse the Idaho Power Company for this loss, and the additional flow was not provided.

Under the Existing Systems Alternative, flow augmentation would likely continue according to the NMFS 1995 Biological Opinion and 1998 Supplemental Biological Opinion. Flow augmentation would continue to be provided as specified each week by the TMT. The ability to meet flow targets would be subject to hydroelectric, flood control, irrigation, navigation, and recreational needs. Under these conditions, it is not likely that flow targets for fish passage could be consistently met on a weekly or daily basis.

Presently, most of the water available in Dworshak and Brownlee reservoirs has been directed toward flow augmentation for juvenile fall chinook migration. NMFS has indicated that flows for juvenile summer migrating salmonids would be given priority over flows for adult fall chinook salmon (NMFS, 1995a). This priority is not likely to change unless additional water becomes available or the summer travel time of migrating subyearling fall chinook is minimized.

Flow augmentation would continue to increase subyearling fall chinook salmon survival during seaward migration. Summer flow augmentation, especially from Dworshak Reservoir, increased subyearling chinook salmon survival from 1992 to 1995 by limiting thermally induced mortality in dry years and reducing predation under all flow conditions (Connor et al., 1999). However, releases of cold water from Dworshak Reservoir for summer flow augmentation may affect growth and time of migration of fall chinook salmon in the Clearwater River. In 1994, flow augmentation included 26 days of releases of 8.7°C (47°F) water that dropped water temperatures in near-shore areas of the Clearwater River from about 16°C (61°F) to 12°C (54°F) when parr were present (Connor et al., 1997). Such a drop could possibly affect smoltification (Arnsberg and Statler, 1996; Connor et al., 1996) and may have led to the high proportion of fish that emigrated as yearlings from 1994 Clearwater river releases of fish (W.P. Connor, USFWS, unpublished data). The problem that occurred in 1994 was corrected by the TMT in 1995 by shaping flow augmentation to benefit both Snake and Clearwater river fish (Connor et al., 1997).

In 1996, however, another potential problem was recognized. A decrease in overall survival for subyearling fall chinook salmon in the Snake River was noted when compared to 1995 (Connor et al., *in press*). One possible cause of this decrease was a reliance on early releases of 20°C (68°F) water from Hells Canyon complex to meet the flow target at Lower Granite Dam. Flow augmentation is a complex process that is difficult to implement. There is no published evidence that flow augmentation would increase adult returns to the spawning grounds at levels required for recovery under ESA. The PATH group has stated that "flow augmentation, while increasing survival, does not appear to have the potential to rebuild stocks" because it does not improve survival at the dams themselves (PATH, 1996).

NMFS will conduct a detailed examination of the effects of flow augmentation under the existing requirement for 34,246.4 m^3 (427 thousand acre-feet) and the proposed study volume of an additional 1 MAF. The results of this analysis will be included in the Anadromous Fish Appendix of the Environmental Impact Statement (EIS) for the Feasibility Study.

6.1.2.3 Collection and Transportation

Transportation has been used to try to reduce the losses of juvenile Snake River salmonids during their downstream migration since 1965 when experiments were started on chinook salmon and steelhead (Ebel, 1974). NMFS conducted research from 1968 to 1989 to determine the comparative survival of juvenile chinook salmon and steelhead that were transported from Snake River dams with those that migrated in the river (Ward et al., 1997). Based on its interpretation of the results of these studies, and with the concurrence of all the fishery management agencies, NMFS began to transport all fish that were collected at Lower Granite Dam in 1976 and at Little Goose Dam in 1977 (Park, 1985 in Ward et al.,1997). Mass transportation of juvenile salmonids was implemented as an operational program by the Corps in 1981 (Independent Scientific Group, 1996). In the Snake River, fish are presently collected and transported at Lower Granite, Little Goose, and Lower Monumental dams.

The NMFS 1995 Biological Opinion requires that chinook salmon smolts collected at Lower Granite, Little Goose, and Lower Monumental dams be transported except when transportation operations do not meet criteria established in the Corps' Juvenile Fish Transportation Plan. Presently, most juvenile salmonids that are collected at Lower Granite, Little Goose, and Lower Monumental dams are transported. In 1996, about 11,222,600 fish (85.8 percent of all fish collected) were transported by barges, trucks, or small tanks loaded onto pickup trucks (Corps, 1997a). The fish transport program begins the last week in March at Lower Granite Dam and starts at Little Goose and Lower Monumental dams based on collection numbers at Lower Granite Dam and expected migration times to the lower two dams (Corps, 1998). Fish transport normally ends on October 31 at Lower Granite, Little Goose, and Lower Monumental dams.

According to the Fish Passage Plan, barges are the main mode of fish transportation during the peak migration season, which begins when total collection at a dam reaches 20,000 fish per day. Truck transportation is used before and after the peak migration period. After collection, fish may be held in raceways for up to 2 days for transport. Collected fish are transported daily during the peak passage period. When the numbers of fish decline to less than 500 fish collected daily during the late summer, fish are loaded into sample holding tanks at Lower Granite and Little Goose dams, examined for the Smolt Monitoring Program, and loaded into trucks. At Lower Monumental Dam, fish are routed to sample tanks when their numbers become low enough for handling. Fish are loaded from raceways to large trucks or transferred from examination facilities to mini-tanks for transportation. During the summer period, collected fish may be sampled every other day to reduce stress.

Fish are released from barges at night at selected sites downstream from Bonneville Dam between the Skamania light buoy at about river mile 140 to Warrendale which is at about river mile 141. During spring, trucked fish are released at Bradford Island next to the Bonneville Dam first powerhouse. From mid-June to the end of the transportation season, trucks and mini-tanks are to be loaded onto barges downstream from Bonneville Dam and transported to a mid-river site where transported fish will be released.

There has been disagreement over the reliance on transportation as the main strategy for recovering Snake River salmonids. While NMFS has supported transportation of Snake River fish, the state and tribal fishery managers have favored an approach that relies less on transportation as the main tool and more on spill to increase juvenile fish survival. In response to these concerns, NMFS included a provision in the 1995 Biological Opinion that spill be initiated when the average flow in the Snake River reaches 85 kcfs at Little Goose and Lower Monumental dams and 100 kcfs at Lower Granite Dam. The NMFS 1998 Supplemental Biological Opinion further addresses the spill and transportation issue by taking a "spread the risk" approach in which both transportation and spill are provided for migrating juvenile salmonids. It has reduced the spill trigger for steelhead at Lower Granite Dam to 85 kcfs.

Concerns about the fish transportation program have included 1) delayed effects on juvenile fish after they are released from barges or trucks, including stress, 2) disease, 3) susceptibility to predation, 4) impaired homing, 5) delayed mortality, 6) whether the timing of downstream migrants would be disrupted by transportation, and 7) whether the smolt-to-adult return rate shown by transported fish was sufficient to provide recovery of Snake River salmon.

The PATH group has addressed the question of whether transportation of fish to the Columbia River downstream of Bonneville Dam can compensate for the effect of the hydrosystem on juvenile

survival rates of Snake River spring/summer chinook salmon during their downstream migration (PATH, 1996). They concluded that "survival to the point of release appears high enough to exceed the interim smolt passage survival goal (50 to 70 percent) from LGR pool to below BON, with delayed mortality no greater than that which occurred during the late 1960s. However, there is uncertainty regarding the magnitude of delayed effects. Therefore, available information and analyses are presently insufficient to answer this question."

NMFS has summarized the results of past juvenile fish transportation studies in its 1998 Supplemental Biological Opinion. Some of their findings include the following:

- Transportation helps reduce the number of juvenile salmonids killed in the existing hydropower system and increases the number of returning adult fish.
- Straying responses of transported fish are small and no greater than natural rates.
- There are no conclusive research results showing that transportation improves returns to spawning grounds or provides sufficient adult return rates to recover upriver runs.
- No precise data have been collected on juvenile mortality during or following transportation.
- There does not appear to be large scale predation on smolts immediately after their release from barges.

To determine whether transportation would benefit Snake River salmon, a comparative survival study started in 1995 with PIT-tagged fish to evaluate transportation of spring/summer chinook salmon from Lower Granite Dam. NMFS has analyzed the 1996 and 1997 returns of adult chinook salmon that migrated to sea in 1995. Preliminary results indicated that the adult return of PIT-tagged fish that were transported was about twice the rate of PIT-tagged fish that were released into the tailrace of Lower Granite Dam and then migrated through the hydropower system. These results are preliminary and will require further analysis of adult fish returns from the remaining fish that migrated out in 1995 and those that migrated in 1996. The initial NMFS analysis indicated that the smolt-to-adult return rate for transported fish was 0.25 percent in 1997 and could be about 1.8 percent after all fish from the 1995 outmigration have returned. Preliminary analyses of the 1998 adult return data of test fish from the 1995 study indicate a survival of 0.47 percent for transported fish and 0.23 percent for those fish allowed to migrate to the river. This is much lower than the rate of 2 to 6 percent which the PATH group has estimated to be necessary to prevent extinction (PATH, 1996). This return was the result of good flow and spill conditions during juvenile fish outmigrations.

IDFG has analyzed the return rates of PIT-tagged fish which have passed the lower Snake River dams by various routes. They found that fish which were not detected and presumably passed via spill or turbines returned as adults at rates equal to or greater than transported fish. Fish that were diverted by screens, conveyed through the dam bypass systems, and returned to the river showed the lowest rates of return. This was thought to be due to the effects of the bypass system. The NMFS analysis compared the adult returns of smolts that were collected, marked, and transported from Lower Granite Dam to those that were collected, marked and released at Lower Granite Dam and subsequently passed through additional mechanical bypass systems at the other Snake River dams. Present operations require that all collected fish be transported so that the actual inriver migrants are those fish that migrate past the dams via the spillways or turbines. It should be noted that these analyses are preliminary and that the small number of fish in the sample may not be sufficient to detect statistically significant differences among groups of fish.

Based on preliminary PIT tag data analysis of 1994 and 1995 data, (NMFS, 1998b) has observed some general patterns which include:

- Fish that were detected at several dams (that is, fish that went through the dam juvenile fish bypass systems) returned at a lower rate than fish that were transported or were detected at only one dam (that is, passed via spill or turbines at other dams).
- Of the 1994 juvenile migration, wild and hatchery steelhead and wild spring/summer chinook transported from Lower Granite and Little Goose dams returned at higher rates than those that passed through the hydropower system. However, the reverse occurred for hatchery spring/summer chinook salmon in 1994 and hatchery steelhead in 1995.
- In 1994 and 1995, about 5 to 15 percent of the PIT-tagged fish that arrived at Lower Granite Dam migrated undetected to below McNary Dam.

In 1997, the Independent Scientific Advisory Board (ISAB) was asked three questions related to the transportation of juvenile salmonids from the Snake River (ISAB, 1998a). The questions asked were:

- Were there significant differences in the survival to adult returns of salmon and steelhead that were transported compared to those left in the river?
- Were there significant differences in the straying rate of fish that were transported as juveniles compared to those left to migrate in the river?
- What is the likelihood that collection and transportation of salmon and steelhead at the lower Snake River facilities and McNary Dam in 1998 will result in an increased return of adult fish compared to those left to migrate in the river?

In response to the question of survival to adults, the ISAB indicated that transportation would probably improve the survival of some stocks of anadromous fish. However, the ISAB qualified this response by noting that it was not known which stocks or populations would benefit and which would suffer from transportation.

The ISAB noted that differences in straying rates sometimes occurred between transported and untransported fish. Higher rates of straying of transported fish appeared to have been related to inadequate imprinting by juvenile fish. This occurred most often when fish were transported by truck. The ISAB also noted that it was not known whether the differences in straying rates were biologically meaningful.

In its response to the question regarding the likelihood that transportation of fish in 1998 would result in higher returns of adult fish, the ISAB stated that the effects of a combined trucking and barging operation were uncertain if all species, life history types, and populations were considered together. The ISAB emphasized that a single action such as transportation had to be considered in view of the variation within and between populations as well as its average benefit.

The ISAB had three major recommendations regarding transportation of juvenile fish. These were 1) that a "spread the risk" approach which divides the juvenile migrants between barging and natural migration be taken throughout the 1998 juvenile fish migration, 2) that trucks not be used to transport fish, and 3) that management actions for salmon and steelhead be as population-specific as possible.

Studies of fish transportation are continuing. Proposed studies for fiscal year 1999 funding include 1) the ongoing comparison of transported juvenile fish to those which remain in the river; 2) evaluating transportation of fish to the Columbia River Estuary; 3) evaluating the effects of the

procedures of collection, transportation, downstream passage, and post-release survival of outmigrating salmonids; 4) evaluating the migration and survival of juvenile salmonids following transportation; and 5) evaluating the influence of transportation on the homing of spring and summer chinook salmon. Most of these studies will not be completed before the 1999 decision date regarding the lower Snake River dams.

Per the Existing Systems Alternative, transportation of juvenile fish would continue under the operations specified in the NMFS 1995 Biological Opinion and the 1998 Supplemental Biological Opinion. This requirement is based on NMFS study data that indicate that transportation benefits spring/summer chinook and is likely to benefit sockeye and fall chinook salmon. The NMFS 1995 Biological Opinion specified that all fish collected at the lower Snake River facilities be transported unless the TMT recommended otherwise based on credible evidence that migration in the river would be beneficial. The NMFS 1998 Supplemental Biological Opinion removes any flexibility for returning fish to the river and now requires that all juvenile salmonids collected be transported. Ongoing studies related to transportation, especially the survival comparison of transported fish to those that migrate in the river, would continue until enough data are collected to make a decision regarding future transportation.

Fish transportation by truck has not been fully addressed in the NMFS 1998 Supplemental Biological Opinion because this operation had started before the final Opinion was signed. The Corps, BPA, and BOR have proposed working within the Columbia River Basin Regional Forum to develop a comprehensive review of the use of trucks versus barges and to make and implement recommendations on each method of transport by December 1, 1998. They also propose that the period when fish are barged extend 2 weeks longer into the summer migration to reduce the number of fish that are trucked.

If future studies show that this practice is not warranted, then data from such studies would be discussed in the Regional Forum. The Regional Forum could develop a new policy for transportation before the start of the next spring migration if one were deemed necessary. It is not likely that a final decision regarding the use of transportation of juvenile salmonids from the Snake River will be made in 1999 because of the uncertainty about past study results, the need for continued studies, and the controversy surrounding the entire issue.

6.1.2.4 Temperature Control

In addition to augmenting flow, Dworshak Reservoir water has been used to control water temperature in the Snake River. Dworshak Dam is capable of providing cold water to lower the temperature of the Snake River in the summer. Cold water releases from Dworshak Dam can improve water temperatures in the Snake River for subyearling chinook salmon during the summer, provided it is released at the most suitable time.

During 1995, cooler water was released from Dworshak Dam for 48 days. This helped maintain suitable water temperatures for subyearling chinook in both the Snake and Clearwater rivers. An indirect benefit of the 1995 flow augmentation may have been reduced smallmouth bass predation on subyearling chinook salmon. Anglea (1997) found that smallmouth bass consumption of subyearling fall chinook salmon in Lower Granite Reservoir in 1995 was lower than in 1994. He indicated that flow augmentation from May to mid-July of 1995 probably decreased temperatures and increased turbidity compared to 1994.

In 1996, Dworshak and Brownlee reservoirs were operated according to a state of Idaho plan that released more water from Brownlee in July and August and delayed the release of water from Dworshak. This differed from the NMFS 1995 Biological Opinion scheduling of reservoir releases, although the total volume of water provided was the same. Flows at Lower Granite Dam decreased in July and increased at the end of August. Lower flows and warm water from Brownlee Dam resulted in water temperatures being 1.0°C (1.8°F) higher in July and 0.4°C (0.8°F) higher in August compared to 1995. Higher water temperatures likely contributed to increased mortality of subyearling fall chinook. Dworshak Dam began releasing cooler water in mid-August, but this provided less benefit to fall chinook because it was likely that many of those fish had not survived the earlier high temperatures.

Under this alternative, Dworshak Dam would continue to provide cooler water to help maintain more suitable summer temperatures in the lower Snake River reservoirs for salmonids. Subyearling chinook migration would have to be monitored to determine when fish would most benefit from flow augmentation at either the Brownlee or the Dworshak reservoirs. Monitoring of water temperatures in the Snake River and Dworshak and Brownlee reservoirs would be necessary so that the most suitable flows and temperatures could be provided to improve subyearling chinook survival.

Flow augmentation and associated temperature control affect the time and rate at which Dworshak Reservoir is drawn down; this in turn affects recreational use in the reservoir. The state of Idaho has expressed interest in maintaining a high water surface elevation in Dworshak Reservoir during the summer for recreational purposes. Brownlee Dam could be used to shape flow augmentation by shifting the time when water was provided. However, it would not be able to help control water temperature in the Snake River unless it is provided with the capability to draw water from greater depths in the reservoir.

Under the Existing Systems Alternative, there would be no major changes in the water temperature regime of the lower Snake River. The periods of upstream migration and spawning by Snake River fall chinook salmon would not be expected to change. Egg incubation, emergence times of fry, and downstream migration would also remain unchanged.

6.1.2.5 Operation at Minimum Operating Pool (MOP) + 0.3048 m (1 Foot)

As previously mentioned, the NMFS 1995 Biological Opinion specifies that the Snake River pools be operated at MOP elevations from April 10 until adult fall chinook salmon begin to enter the lower Snake River (usually late August). The Opinion also allows for operation of the pools within 0.3048 m (1 foot) of MOP for approved research. Drawing down the pools increases water velocity, reduces travel time of juvenile fish through the reservoirs, and improves their survival (NMFS, 1995c).

The lower Snake River pools have often been operated at the MOP plus 0.3048 m (1 foot) elevation to provide additional depth for navigation. This has occurred at Lower Granite, Ice Harbor, and Little Goose reservoirs. The Corps has prepared an environmental assessment for dredging of shoals in the Lower Granite and Little Goose pools to provide the authorized navigation depth of 4.3 m (14 feet). This dredging would allow operation of these pools at MOP. Under the Existing Systems Alternative, this operation would continue until shoaling in the navigation channel again required dredging.

6.1.2.6 Turbine Operation within 1 Percent of Peak Efficiency

The NMFS 1995 Biological Opinion calls for operation of turbines within 1 percent of peak efficiency during the juvenile and adult fish migration seasons. Previous studies have found that operating turbines at peak efficiency provides the highest survival of anadromous fish that pass through turbines. In general, turbines have been operated within the 1 percent of peak efficiency range at the Snake River dams when possible. Turbines would continue to operate within one peak efficiency under this alternative unless future studies provide compelling evidence to operate at other levels of efficiency.

6.1.2.7 Other Associated Operations

Continued monitoring and maintenance of ongoing operations of dam operations, fishways, and fish transportation systems are necessary to ensure that adult and juvenile fish are not adversely affected. The Corps has an established monitoring and maintenance program to prevent outages and equipment breakdowns. However, mechanical failure and human error that can cause fish mortalities may occur despite the best efforts that are made to prevent such problems. In general, fish passage facilities operate to established criteria in the Fish Passage Plan. Examples of problems that have occurred include adult steelhead and chinook that stranded themselves after jumping at water flowing from an orifice in the juvenile fish collection channel at Ice Harbor Dam; submersible traveling screen failures at Lower Monumental Dam; and four incidents involving fish loss at Little Goose and Lower Granite dams in May 1998 caused by orifice clogging, shifting of equipment, and human error. Under the Existing Systems Alternative, incidents involving equipment failure or malfunction and human error are unavoidable and would continue. The frequency and severity of such incidents cannot be predicted.

6.1.3 Planned Modifications

Juvenile fish collection and bypass system improvements discussed in the NMFS 1995 Biological Opinion include installation of extended length screens at Lower Granite and Little Goose dams, improvements to the juvenile bypass system at Lower Granite Dam, and installation of extended length screens at Lower Monumental and Ice Harbor dams. Installation of flow deflectors (fliplips), where they do not now exist and modification of some existing deflectors have also been proposed and implemented to decrease TDG levels that result from spill.

6.1.3.1 Extended Length Screens

Extended length submersible traveling screens would increase survival of subyearling fall chinook salmon smolts, provided that they are kept debris-free and descaling does not become extreme. In 1995, experimental 12-meter-long (40-foot), extended-length screens were installed in one of six turbine intakes at Lower Granite Dam. Extended-length screens were installed in all six turbine intakes at Lower Granite Dam in 1996. Connor et al. (in press) reported that fish guidance efficiency at Lower Granite Dam for naturally produced subyearling fall chinook salmon increased from 47 ± 7 percent in 1995 to 68 ± 10 percent in 1996.

Extended-length screens were installed at Lower Granite and Little Goose dams and have increased the numbers of fish diverted from turbines into fish bypass systems. However, they have also diverted greater amounts of debris into the fish collection and bypass system which tends to clog the bypass openings. This increases the potential for injuring or killing juvenile fish. The Corps

presently plans to study the effects of larger bypass system orifices on fish condition and debris accumulations.

6.1.3.2 Juvenile Bypass Improvements

The Corps has completed a feature design memorandum for the juvenile fish bypass system improvements at Lower Granite dam and had planned to complete the modifications by 1999. This action has been deferred pending the outcome of the 1999 decision on drawdown of the lower Snake River facilities.

6.1.3.3 Flow Deflector Installation

The NMFS 1995 Biological Opinion Reasonable and Prudent Alternative Measure 19 calls for a program to reduce gas supersaturation at Ice Harbor Dam as soon as possible. The Corps has installed spillway deflectors (flip lips) on eight of the ten spillbays at Ice Harbor Dam and plans to install deflectors on the two end bays during fiscal year 1999. The spillway deflectors appeared to have changed current patterns downstream from the dam which may have affected adult fish entry to the fish ladder. Changes in current patterns also reportedly affected entrance and exit conditions at the downstream end of the navigation lock. A concrete wall will be built to reduce turbulence near the north shore fish ladder to improve guidance of adult salmonids to its entrance. A series of rock filled coffer cells will be placed in the river near the lock entrance. The coffer cells are intended to deflect river currents from this area and improve conditions for navigation.

Installation of the eight spillway deflectors at Ice Harbor Dam has significantly reduced gas supersaturation downstream from Ice Harbor Dam. This has allowed for increased volumes of spill for juvenile fish passage, while maintaining TDG levels within state water quality waiver standards. However, this measure is only able to maintain TDG at state standards or waiver levels when spill can be controlled. It is unlikely that the installation of flow deflectors alone would control gas supersaturation under conditions of forced spill or (for example, lack of power demand, turbine outages, and power transmission problems). The involuntary or forced spill conditions which produce TDG levels higher than 125 to 130 percent have the greatest impact on potential fish mortality.

6.1.4 Pacific Lamprey

Presently, lamprey populations are declining in the Columbia and Snake rivers. Passage problems at mainstem dams for both adult and juvenile lamprey during their migrations have been pointed out among the possible factors responsible for this decline. Lack of an adequate bypass system at mainstem dams may subject juvenile lamprey to greater passage through the turbines at these facilities. Long (1968) in Close et al. (1995) reported that most juvenile lamprey entered turbine intakes near the center and bottom. Presently, most screen systems do not extend deep enough into the water column to prevent entrainment of juvenile lamprey into turbine intakes. There have been no studies to determine the survival of juvenile lamprey that use various routes such as turbines and bypass and collection systems for juvenile salmonids to pass dams. Hammond (1979) reported that juvenile lamprey were found impinged on traveling screens that were designed to divert juvenile salmonids.

Downstream migration may also be affected by the impoundments created by dams. Juvenile lamprey depend on river flow and currents to transport them downstream. The dam and reservoir system in the Columbia and Snake rivers has also changed the hydrograph resulting in lower flows in

the spring and early summer when juvenile lamprey migrate to the ocean. Impoundments which slow the travel time of water may also retard the downstream movement of juvenile lamprey. The effect of increased populations of predators in the reservoir environment is unknown, but may be a cause of increased juvenile mortality.

Production will continue to decline or remain at very low levels. Passage problems and suitable habitat are the main causes of this decline.

6.1.5 American Shad

This species has steadily increased in production with each of the four successive dams being built on the lower Snake River. Normal production fluctuations will occur on an annual basis.

6.2 Resident Fish (with Existing Systems Alternative)

Continuing the existing fish programs would have little effect on resident fish. Resident fish populations have been limited in the past by historical dam operations. Fluctuating water levels have affected spawning success, habitat quality in shallow water and embayments, and food abundance. However, current operations minimize water level fluctuations by operating at MOP from April 10 through the onset of adult fall chinook migration into the lower Snake River (usually late August), greatly reducing the likelihood of dewatering eggs or leaving fry and juveniles stranded.

6.2.1 Native Species

Generally, native species would continue to do best in the more riverine segments of the habitat, for example, the tailwater areas and the historic river channel. Cold-water resident species, such as rainbow trout, bull trout, and mountain whitefish, would continue to use the reservoirs infrequently as corridors or over-wintering habitat. Other resident native species populations would likely continue at current levels. Chiselmouth and both species of suckers would continue to be abundant throughout all four reservoirs. Numbers of redside shiners declined from the mid-80s to the early 90s. Their population numbers would persist at a level less than that formerly found. This species would continue to be common in lower Snake River reservoirs. Peamouths, sand rollers, and sculpins would continue to be uncommon. Northern pikeminnow numbers may be impacted by the continuation of the predator control sport-reward program. This would depend on the amount of effort directed at removing large northern pikeminnow from the lower Snake River population.

6.2.1.1 White Sturgeon

The Existing Systems Alternative has no planned improvement to increase white sturgeon passage at the dams. If the Existing Systems Alternative is implemented, white sturgeon sub-populations would continue to be isolated between dams on the lower Snake River. Spawning habitat, at best, would continue to be limited for white sturgeon in the reservoirs downstream of Lower Granite Dam. Some juvenile sturgeon from the Hells Canyon Reach would continue to move downstream past the dams and be lost to that sub-population. They would, however, provide recruitment to the lower Snake River sub-populations. Overall abundance would continue at low levels.

6.2.2 Non-native Species

Non-native species would continue to require shallow areas with zero to low water velocities for spawning and rearing success. Sport fisheries would continue on smallmouth bass, channel catfish, yellow perch, rainbow trout, white and black crappies, and bullheads. Exploitation levels could

increase somewhat, possibly impacting size and age structure of the populations. Carp would continue to be abundant and to degrade shallow water habitat by rooting up vegetation and increasing turbidity.

6.3 Invertebrates (with Existing Systems Alternative)

Continuing the existing fish programs would have little effect on invertebrate populations. Worms and midges would continue to dominate the benthic community, and diversity would remain low. Mollusc populations would continue to be dominated by the introduced Asian clam. Crayfish would continue to provide an important link in the food chain, being prey for several species including northern pikeminnow, channel catfish, smallmouth bass, and white sturgeon. A potential threat is the swiftly expanding range of the zebra mussel (*Dreissena polymorpha*).

6.3.1 Zebra Mussels

Exotic fouling organisms such as the zebra mussel will be a threat to the continued operation of fish facilities at all dams should they become established in the Columbia River Basin. The zebra mussel is native to the drainage basins of the Black, Caspian, and Aral seas and was introduced into several European freshwater ports in the late 1700s. Since that time, it has spread throughout Europe's inland waterways (O'Neill and MacNeill, 1991). Zebra mussels were probably introduced to North America into the Great Lakes in 1986 and have rapidly colonized all of the Great Lakes, and the Susquehanna, Illinois, Hudson, Mississippi, Missouri, Tennessee, and Ohio rivers. Zebra mussels have not been found west of the Rocky Mountains yet, but are likely to eventually be introduced to waters in the western United States.

Zebra mussels have caused problems by clogging water intakes of electrical power plants, municipal water supplies, and industrial plants in other areas of the United States such as the Great Lakes. Trash racks, tunnels, pipes, and other structures associated with water intakes provide ideal habitat for zebra mussels since they provide a continuous flow of water that supplies a constant source of food and oxygen and also carries away waste products. Populations of zebra mussels can reach extremely high densities, reportedly as high as 750,000 mussels per square meter (897,000 mussels per square foot) at a Great Lakes utility (O'Neill and MacNeill, 1991).

WDFW developed a risk assessment to estimate the potential impact of zebra mussels on fish and wildlife resources in Washington State (Zook, 1995). This assessment indicates a high probability that zebra mussels will become established in Washington State within the next 5 to 10 years. Washington, other northwest states, and the western Canadian provinces all have abundant, suitable habitat for zebra mussels. Of the western states, California is the only one with an inspection program for zebra mussels. The Corps has monitored the Snake River dams for zebra mussels, but has found none to date.

There is great potential for zebra mussels to colonize fish passage facilities at Snake River dams. Zebra mussels prefer water velocities of 0.15 to 0.46 m/sec (0.5 to 1.5 feet/sec) and summer temperatures between 20 and 25°C (68 and 77°F). However, they can tolerate velocities up to 2.0 m/sec (6.6 feet/sec) and temperatures between 0 and 30°C (32 and 85°F); (Zook, 1995). Juvenile fish facilities would be especially vulnerable to infestation by zebra mussels because of the low current velocities required under present screen criteria for juvenile fish. Adult fish facilities would be less suitable for zebra mussel colonization because higher water velocities in those structures would prevent settling of mussel larvae. However, any areas of slower water velocities would be susceptible to colonization. All water intake and conveyance structures would also be susceptible to

zebra mussel infestation. Passage of adult salmonids at the dams would be impaired if adult fish facilities could be maintained to meet established criteria.

Methods to control zebra mussels are limited, and most of those that are available would be costly, impractical, or detrimental to salmonids. These methods include maintaining high water velocities at structures that are prone to colonization, electrically charging structures, heating intake water, applying chemical control, filtering all intake water, and physically scraping mussels from structures.

Zebra mussel infestation of fish passage facilities would affect fish by clogging structures so that physical criteria such as water velocities could not be met or maintained and by causing physical injury to fish that come in contact with their shells. Approach velocities to fish screens and surface collectors would be greatly altered if the screens became clogged by mussels. Water velocities within bypass facilities would also be changed. Systems that supply additional water to attract adult fish to fish ladders would also be impacted by zebra mussel colonization.

Under the Existing Systems and Surface Bypass/Collector Alternatives, spill may provide the safest means of passing juvenile salmonids at the Snake River dams if zebra mussels become established. Zebra mussels are less likely to establish on spillways since those structures are dry during much of the year, and water velocities are much higher in the spillways than can be tolerated by mussel larvae during their settling and attachment period. Juvenile fish are also not likely to come in contact with the spillway surface during their passage.

6.4 Terrestrial Resources (with Existing Systems Alternative)

The Existing Systems Alternative would have virtually no effects on vegetation/habitat in the study area. Therefore, this analysis is simply looking at a future without a project scenario. Table 5.3 shows the amount of habitat in the study area before inundation and the changes in habitat in a recent 10-year period (from 1987 to 1997), which may give insight into future vegetation changes. Since the 1997 cover typing effort involved much more extensive ground-truthing, it detected some errors in the earlier cover typing effort. These errors accounted for only a small portion of the changes noted. The vast majority of the changes was from management activities on HMUs and other facility lands, natural vegetation development along the reservoir shorelines, and acquisition of additional facility lands along the lower Snake River.

6.4.1 Riparian Habitat

Riparian forest increased by 137 ha (339 acres) from 1987 to 1997. About 44.5 ha (110 acres) of this increase was from additional site acquisitions, leaving 92 ha (228 acres) of increase (an average of 9 ha [23 acres] per year) from management activities, succession of earlier tree plantings from shrubs to trees, and natural revegetation along the shorelines. It is unlikely that riparian forest would continue to increase at this same rate since many of the tree plantings have now matured to the riparian forest type, and the Corps has reached the acreage limit for habitat acquisition approved under the Compensation Plan. Although riparian forest acreage may not increase substantially in the future, it should continue to develop in structure and diversity, depending on reservoir operations and continued irrigation of HMUs. Downs et al. (1996) concluded that lower Snake River riparian community species composition appeared to depend on a complex interaction of substrate and water level changes. It is difficult to predict what future water level operation changes may occur to address salmon recovery. While the March 1992 drawdown had little effect on riparian tree species, it did affect riparian shrubs (palustrine scrub-shrub habitat) (Phillips, 1993).

Palustrine scrub-shrub habitat increased from 114 ha (281 acres) in 1987 to 240 ha (592 acres) in 1997 (Table 5.3). Less than 1 acre of this increase was due to recent land acquisitions. Therefore, about 126 ha (310 acres) of the increase was due to management activities on HMUs and other facility lands, as well as natural revegetation along reservoir and tributary shorelines. Downs et al. (1996) found palustrine scrub-shrub vegetation along the lower Snake River increasing along bars that are somewhat protected from wind and wave erosion. Management plans for facility lands do not indicate potential for future significant increases in palustrine scrub-shrub habitat (Corps' letter supplements for each HMU, various years). Although the March 1992 drawdown significantly increased palustrine scrub-shrub habitat, future reservoir operation changes may enhance or hinder further increases in this habitat depending on timing, duration, and frequency of water level changes; major climactic changes; shoreline conditions (slope, aspect, and substrate); and, other ecological conditions. Therefore, future palustrine scrub-shrub quantity or quality would be difficult to predict.

While mesic shrub habitat increased from 241 ha (596 acres) in 1987 to 317 ha (782 acres) in 1997, almost all of this increase can be accounted for with recent land acquisitions along the lower Snake River. There may be some additional increases in this habitat in the future since grazing has been removed from facility lands, allowing for development of more mesic shrub habitat and better quality habitat. Also, management activities on HMUs and other facility lands in the future may increase mesic shrub acreage and quality.

Palustrine emergent habitat increased from 22 ha (54 acres) in 1987 to 143 ha (353 acres) in 1997 (Table 5.3). Most of the change was from natural conditions along the reservoir and tributary shorelines, but a small amount could be attributed to management activities on HMUs. None of the change was apparently due to land acquisitions. Downs et al. (1996) found that emergent wetlands increased significantly at some of the main tributaries due to sedimentation at the mouth of the tributaries, thus improving wetland conditions. This has occurred at some of the backwaters, embayments, and other shoreline areas. Emergent wetland development would likely continue in these areas as sediments continue to accumulate. As sediments continue to deposit, wetlands may transition to various riparian habitats. Little change in amounts of emergent wetland vegetation would be expected elsewhere in the future with current reservoir management, unless wetland management activities are initiated on facility lands. Future water level operations could allow additional cattail, bulrush, and other emergent plant species to become established and cause sediments to build up, as occurred following the March 1992 drawdown. As the sediment level increases, those plants are then sometimes able to survive inundation which earlier had precluded long-term survival.

There was a decrease in AFG habitat of over 121 ha (300 acres) between 1987 to 1997. Most of this change was from various plantings and other management activities that took place in AFG habitat after 1987 and some errors in the 1987 cover typing. There may be some additional changes in the amount of this habitat in the future, depending on management actions, although changes would likely be relatively minor.

6.4.2 Upland Habitats

Shrub-steppe and grassland habitat acreage increases from 1987 to 1997, 1,997 (808 ha) and 297 ha (734 acres), respectively, were from land acquisitions and should not change much in the future. Habitat quality should improve, at least slightly, as grazing restrictions are continued and the habitat continues to recover. Dobler et al. (1996) suggested that reducing annual grasses (primarily, introduced bromes) would benefit two important shrub-steppe obligates (sage thrasher and sage

sparrow), while apparently harming none of the other species using the community. Results of this and other studies could be used to guide shrub-steppe habitat improvement on facility lands. Agricultural land acreages should not change much in the future as the Corps is already attempting to achieve optimal agricultural benefits for wildlife based on HEP.

6.4.3 Habitat Evaluation Procedures

As stated above, very few specific habitat measurements needed for HEP have actually been made at the various HMUs. While the techniques used in the modified HEP method have been useful for estimating how the development and management of facility and off-facility lands may mitigate for losses, they fall short of the precision found using measured HEP techniques. One of the agreements reached in the LOA was that specific habitat measurements would be made for each HEP model at each of the HMUs and other facility lands upon acquisition of all properties and completion of planned habitat developments. Also, measured HEP techniques were to be used every 10 years following the initial effort to monitor habitat changes. This was intended to more accurately assess compensation efforts. Unfortunately, acquisition of suitable property for establishing habitat management was difficult, and the Corps has not funded some of the needed development and habitat management activities, which continues to postpone the measured HEP effort.

However, completing detailed HEP analyses at those areas with developments and habitat management implemented now, rather than waiting for completion of development and management of all lands, would be important for determining (1) a closer approximation of HUs credits and compensation balances, (2) success of current habitat management activities, and (3) changes needed in habitat management to improve HU compensation. Understanding how current management activities affect HUs could help determine changes needed in existing management strategies, as well as shaping development and management of HMUs still in early development.

6.4.4 Wildlife Resources

The Existing Systems Alternative would have virtually no effects on wildlife in the study area. Therefore, this analysis simply looks at a future without a project scenario.

As mentioned earlier, while it is unlikely that riparian forest would increase significantly in acreage in the future, the quality of the riparian forest should continue to improve. Therefore, some wildlife that has not yet been documented within the study area, or wildlife that is present, but in small numbers with limited distributions, would find the habitat satisfactory in the future. This wildlife could include waterfowl (such as wood duck), cavity-nesters (such as Lewis' woodpecker and western screech owl), certain NTMBs (such as olive-sided flycatcher and red-eyed vireo), certain raptors (such as, great horned owl), some mammals (such as, deer, raccoon, and bobcat), and amphibians and reptiles (such as, Pacific tree frog).

Future palustrine scrub-shrub habitat quantity and quality would be difficult to predict; therefore, it would likewise be difficult to predict what would happen to those wildlife species dependent on this habitat.

Since mesic shrub habitat acreage and quality would likely increase in the future, wildlife species associated with it (such as, gamebirds, song sparrow, lazuli bunting, and deer) should also benefit.

Riparian habitat should continue to improve in quality and quantity over time. This should help those wildlife species within the study area that use these areas as travel corridors, for migration, daily

movements, and the dispersal of young. It may also facilitate the movement of some wildlife species back into the study area that were eliminated with the inundation of the four reservoirs.

These habitat types would only extend to the outer limits of moisture influence. On irrigated HMUs, this would be primarily within the irrigated circles. In natural drainages, it would be limited to the immediate canyon bottoms.

Since upland habitat acreages and values would likely change little in the future, there would likely be only small changes, if any, to wildlife using those habitats.

7. Future with Maximum Transport of Juvenile Salmon Alternative

7.1 Anadromous Fish (with Maximum Transport Alternative)

The Maximum Transport Alternative would increase the number of migrating juvenile salmonids that are collected at Lower Monumental, Little Goose, and Lower Granite dams, transported from these facilities , and released downstream from Bonneville Dam. The number of fish that are transported would increase moderately over existing conditions because the percentage of fish presently collected is already fairly high.

The overall effect of the Maximum Transport Alternative on survival and recovery of Snake River spring/summer chinook salmon is expected to be similar to the Existing Systems Alternative. Analyses by NMFS (NMFS, 1999) and PATH (Marmorek et al., 1998b) indicate that the 24-year and 100-year survival and recovery probabilities for spring/summer chinook salmon would be similar for the Existing Systems and Maximum Transport (both with and without surface collectors) alternatives. However, these probabilities would be lower than those for the Natural River Drawdown alternative.

The effect of the Maximum Transport Alternative on steelhead would differ slightly from that on spring/summer chinook salmon. Steelhead have a higher fish guidance efficiency than spring/summer chinook salmon so a higher percentage of steelhead than spring/summer chinook are transported under the Existing Systems Alternative. The PATH group (Marmorek et al., 1998b) compared the Maximum Transport and Existing Systems alternatives and reported that the percentage increase in steelhead that are transported under the Maximum Transport Alternative may be lower than for spring/summer chinook salmon. This would reduce the benefit of the Maximum Transport Alternative on the direct survival of steelhead. However, it would reduce the potential adverse impact of transportation on mortality of fish after they are released downstream from Bonneville Dam. In general, the relative effect of the study alternatives was determined to be similar to the effect on spring/summer chinook (that is, Existing Systems and Maximum Transport effects were similar, and the Natural River Drawdown had a higher probability of meeting survival and recovery standards).

For fall chinook salmon, PATH analysis showed that the Existing Systems, Maximum Transport, and Natural River Drawdown alternatives all exhibited high average probabilities of meeting or exceeding the short-term survival escapement standards. Drawdown was found to produce probabilities that exceeded critical levels for recovery of fall chinook. The Existing Systems and Maximum Transport operations would also meet recovery standards if the future relative survival of both transported and non-transported fish is greater than in the past. However, they would not meet the recovery standard if future relative survival is the same as in the past. In those cases where future and past survival are the same, it was stated that stopping transportation and retaining the current configuration of the hydrosystem could achieve recovery standards (Peters et al., 1999).

Under the Maximum Transport Alternative, voluntary spill would be eliminated at Lower Monumental, Little Goose, and Lower Granite dams. Ice Harbor Dam does not have transportation facilities, so spill would continue at this facility. Potential impacts of gas supersaturation on fish would be reduced since total dissolved gas levels (TDG) would be lowered from the 115 to 120 percent allowed under state water quality waivers to the 110 percent TDG/level required by water

quality standards. However, monitoring of aquatic life at TDG levels of 115 to 120 percent has not shown adverse impacts. Elimination of voluntary spill would, therefore, not be expected to have a significant effect on anadromous fish. However, involuntary or forced spill would continue. TDG levels during periods of involuntary spill can be harmful to fish. The overall effect of this alternative on TDG supersaturation resulting from involuntary spill is expected to be similar to that of the Existing Systems alternative.

7.2 Resident Fish (with Maximum Transport Alternative)

As with the Existing Systems Alternative, the Maximum Transport Alternative would have little effect on resident fish species. It is possible, but not expected, that an increase in entrained fish would occur. Also, it is not likely that dam passage for white sturgeon would improve with this alternative.

7.3 Invertebrates (with Maximum Transport Alternative)

See Section 6.3.1, which details information on potential impacts of future zebra mussel infestations.

7.4 Terrestrial Resources (with Maximum Transport Alternative)

The future with Maximum Transport Alternative would be the same as that discussed above for the Existing Systems Alternative.

8. Future with Surface Bypass/Collector Alternative

8.1 Anadromous Fish (with Surface Bypass/Collector Alternative)

Surface flow bypass is still an experimental concept that is being tested in the Columbia River system. The surface bypass/collection (SBC) prototype at Lower Granite Dam is one of several facilities being tested to evaluate surface flow bypass concepts. Prototype surface flow bypass systems are also being tested at Wanapum and Rocky Reach dams and at the Bonneville Dam first and second powerhouses. These facilities are being measured against the fish passage standard at Wells Dam, which has been the most successful surface bypass constructed to date. About 89 percent of all migrating juvenile salmonids have been found to pass Wells Dam via the surface bypass (Skalski et al., 1996). Dauble et al. (1999a) compared the performance of the prototype surface flow bypass facilities and ranked the Lower Granite Dam SBC as "middle of the road." Surface flow bypass efficiency was determined to be higher at the Wells and Bonneville first and second powerhouse facilities than at Lower Granite Dam and lower at Wanapum and Rocky Reach dams.

8.1.1 Current Study Status

A prototype SBC was installed at Lower Granite Dam in 1996 and tested during the 1996, 1997, and 1998 migration seasons. The prototype SBC was studied by researchers using radiotagged fish and hydroacoustic techniques to determine its effectiveness in attracting and passing juvenile salmonids. Johnson et al. (1997), using hydroacoustic equipment, found that the SBC entrance efficiency was about 70 percent for fish within 3 m (10 feet) of the entrance during spring 1997 monitoring. However, they expressed concern that 30 percent of the fish did not enter the SBC. The effectiveness of the SBC was found to be close to four times greater than spill effectiveness in terms of smolts diverted per volume of water. The incremental benefit provided by the SBC over the screen system itself was found to be relatively small (4 to 7 percent). Use of both the SBC and the existing turbine intake screen system was found to be necessary to achieve the desired level of fish protection. About 37 percent of the outmigrant fish were estimated to have passed the test area via a non-turbine route without use of the existing screen system.

Adams et al. (1997) found that 13 percent of chinook salmon radiotagged in 1997 passed within 10 m (33 feet) of the SBC and that 51 percent of those fish (6 percent of the total) entered and passed through the structure. They also found that 91 percent of the other fish that approached within 10 m (33 feet) of the SBC passed under it and into the turbine intake screen and bypass system. Results from the 1996 and 1997 studies showed that many of the fish that approached the SBC at depths of less than 9 m (30 feet) went under or around the structure. Most of the fish that approached at depths greater than 9 m (30 feet) went under the SBC.

In 1998, researchers tested a surface bypass system that was modified based on the results of the 1996 and 1997 tests. Changes to the SBC for 1998 included a modified collector patterned after the Wells Dam bypass and a behavioral guidance structure. The modified collector was designated as the simulated wells intake (SWI). The SWI was attached to the dam face below the SBC to extend the bottom of the SBC by 6 m (20 feet). The SWI was installed to reduce downward flow in front of the

SBC for a distance out to 30 m (98 feet). The intent of this modification was to reduce fish entrainment into the turbine flow and improve the opportunity for fish to find the SBC entrances.

A behavioral guidance structure (BGS) was tested to determine if it would guide migrating juvenile salmonids toward the SBC and prevent them from entering turbine units 1, 2, and 3 at the southern half of the powerhouse. The prototype SBC is located above turbine units 4, 5, and 6. The BGS is a 335-meter-long (1,100-foot-long) steel wall, suspended by floats, that separates the forebay into two sections in front of the powerhouse at Lower Granite Dam. It is 24 m (79 feet) deep at the downstream end and tapers to 17 m (56 feet) deep at the upstream end.

In general, researchers found that the BGS showed potential to improve surface bypass efficiency, but that the volume and pattern of flow through the SBC were not sufficient to effectively attract and guide juvenile salmonids into the SBC entrances. Cash et al. (1999), used radiotagged fish, and Johnson et al. (1998) and Evans et al. (1999) used hydroacoustic equipment to show that the SBC with the SWI and BGS diverted more juvenile salmonids into the area immediately upstream of the SBC in 1998 compared to 1997. However, they did not observe a similar increase in the proportion of fish entering the SBC. They reasoned that more fish did not enter the SBC because the volume of water passing through it was too small or because the flow pattern was incorrect.

Adams and Rondorf (1999) summarized radiotagging and hydroacoustic studies, conducted by the USGS Columbia River Research Laboratory (CRRL), of juvenile fish passage at Lower Granite Dam in 1998. They reported that 46 to 56 percent of the fish detected passing the dam were guided via the fish screens while 14 to 34 percent passed through the SBC. They also reported that, depending on species, 34 to 64 percent of the fish detected at the dam approached within 10 m (33 feet) of the SBC entrances. Of the fish that came within 10 m (33 feet) of the SBC, 14 to 51 percent entered and passed through the SBC, 30 to 53 percent passed under the SBC, and 12 to 25 percent went around the south end of the SBC.

The BGS was found to be 61 to 92 percent effective at diverting radio-tagged fish from turbines 1, 2, and 3. Adams and Rondorf (1999) also reported that the BGS was about 80 percent effective in diverting fish away from turbines 1, 2, and 3. Johnson et al. (1998) also reported similar performance for the BGS, but cautioned that 1998s first-year results were not sufficient to make a long-term decision. They noted that Turbine number 2 was not operating during the entire test and recommended that the BGS be studied with Turbines 1, 2, and 3 under full load. Adams and Rondorf (1999) also reported that a higher proportion of radiotagged fish, between 34 and 64 percent, came within 10 m (33 feet) of the SBC in 1998 than in 1997. This resulted in more spring migrants approaching the SBC in 1998 than 1997. However, the percentage of spring migrants that actually passed through the SBC increased only slightly for hatchery steelhead, was about the same for wild steelhead, and decreased for hatchery spring chinook salmon in 1998 compared to 1997. The percentage of summer migrants (primarily fall chinook) that came within 10 m (33 feet) of the SBC and passed via the SBC doubled in 1998 (49 percent) compared to 1997 (24 percent).

The SWI did not appear to alter the vertical distribution of spring migrating fish in front of the SBC. A larger percentage of these fish approached the SBC at depths shallower than 9 m (30 feet) in 1997 when there was no SWI, than in 1998 when the SWI was in place. The SWI appeared to benefit summer migrants. More summer migrants approached the SBC at shallower depths in 1998 than in 1997 and the efficiency of the SBC increased in 1998 compared to 1997. Cash et al. (1999) noted that the higher SBC efficiencies seen for summer migrants may have been due to a greater proportion of the total river flow that passed through the SBC.

Concerns were expressed during the development of the study design for the SBC and BGS regarding the impacts of these structures on predation upon juvenile fish and migration of adult salmonids. Both of these structures may provide greater opportunities for predation by northern pikeminnow since they would divert and concentrate juvenile salmonids. There were also concerns about increased predation in the tailrace of Lower Granite Dam. Adult fish may also be affected if they encountered the structures and are delayed or fall back past the dam. Predation studies were conducted to determine if the SBC or BGS were increasing habitat or opportunities for predators. Researchers have also monitored the movements of radiotagged adult salmonids after they leave the Lower Granite Dam fish ladder. Results of the 1996 to 1998 studies do not indicate problems with adult passage or predation on juvenile salmonids due to the presence of the prototype SBC and BGS.

Piaskowski et al. (1998) indicated that the potential for predation on juvenile salmonids by northern pikeminnow near the SBC in the forebay and by smallmouth bass in either the forebay or the tailrace is low because of the small numbers of these predators and because they did not congregate near the SBC. They suggested that predation by northern pikeminnow could be significant if river flows are low, and there is little or no spill when juvenile salmonids are passing through the SBC and over spillbay.

Potential impacts of the BGS on adult salmonid migration have been studied. Reischel et al. (1998) found that migration routes of radiotagged adult chinook salmon were similar in 1998 when the BGS was being tested to 1997 before the BGS was installed (Reischel et al., 1998). The effect of the SBC and BGS on fallback rates of adult fish has not yet been assessed, but will be determined after data from all radiotagging studies have been analyzed.

Under the Surface Collection/Bypass Alternative, it is likely that continued refinement and study will be necessary. The ISAB (1998) reviewed current information regarding surface bypass technology for the Columbia Basin facilities in response to a request from the Northwest Power Planning Council. The ISAB recommended the following: 1) the Corps should continue development and testing of surface bypass; 2) priority should be given to listed species, but that the effects on all species and life history types of native fish should also be understood; 3) surface bypass development should take into account the need to protect the widest possible biological diversity; and 4) about 10 years should be provided to ensure proper and full evaluation of surface flow bypass systems. Johnson et al. (1997) also noted that the Wells Dam surface bypass took 12 years to fully develop and evaluate.

Presently, it does not appear that enough information has been collected to conclude that the SBC prototype at Lower Granite Dam alone could operate with a fish passage efficiency similar to the Wells Dam facility. Johnson and Adams (1998) noted that the current information base on surface bypass was not sufficient to make a sound decision in 1999. They also stated that the BGS still has to be tested with all of the turbines behind it operating. Both Evans et al. (1999) and Cash et al. (1999) noted the need to examine flows in front of and into the SBC to improve the guidance of juvenile salmonids into the structure. Additional monitoring is being conducted in 1999, and a final year of study will occur in 2000. The SBC is scheduled to be removed after the 2000 testing.

Based on existing study results, it is also likely that operation of the SBC with the existing fish screen system and a spill program would be needed to meet fish passage efficiency standards. Dauble et al. (1999a) noted that performance of the SBC has not been adequate for it to be used as a stand-alone fish bypass measure. However, they stated that the SBC when used in combination with the existing intake screens was efficient at diverting smolts from turbines at Lower Granite Dam. They also

indicated that a SBC system also complements spill as a smolt protection measure. Johnson et al. (1998) concluded that the combined use of spill, intake screens, and the SBC/SWI/BGS provided a high level of protection to smolts (a fish passage efficiency of 92.6 ± 1.2 percent) during the spring of 1998 at Lower Granite Dam.

8.1.2 Facility Effects

Under the Surface Bypass/Collection Alternative, juvenile salmonid passage at the Snake River dams would be improved if this concept is successfully developed from a prototype to a full-scale operation. To be successful, the SBC would have to increase the fish passage efficiency at each dam to a level comparable to that at Wells Dam. At Lower Granite Dam, fish passage efficiency would have to increase by at least 6 to 13 percent over that which can be achieved by the existing juvenile fish collection and bypass system. Adult fish migration would not be changed from the Existing Systems Alternative as long as attraction flows to the SBC do not direct fish from the ladder exits to the SBC, and the BGS, if installed, does not delay upstream migration.

Increased predation upon juvenile salmonids by northern pikeminnow and other predators may occur in and near the SBC, the BGS, or the tailrace if predator populations increase. The structures may also concentrate juvenile salmonids and provide greater opportunities for predators.

General findings of the radiotracking study may be applicable to the effects of SBCs and BGSs at the other lower Snake River dams. However, installation of an SBC and a BGS at other dams would require additional study to ensure that the unique characteristics of each site are examined and that adult fish passage is not adversely affected. The ISAB (1998a, b) also noted that each dam would have to be individually adapted and tested with a specific prototype because of structural differences between Wells Dam, where surface bypass is most successful, and other dams.

Survival rates of juvenile salmonids after passing through the SBC would vary depending on whether they were returned to the spillway, returned via the fish bypass system, or collected and transported. The SBC system would have to be dewatered to a manageable volume if fish were to be bypassed to transportation facilities or returned to the river without injury. Dewatering of the bypass system so that juvenile fish can be transported must be addressed in detail to determine its feasibility. Survival of juveniles using these routes of passage to the lower Columbia River would be similar to the survival rates presently observed for those routes.

Questions remain about how the flow volume needed for effective operation of the SBC can be reduced if fish are to be routed through bypass pipes to transportation facilities. Dauble, et al. (1999a) suggested that it might be best to separate the SBC from transportation so that dewatering is not necessary. They noted that dewatering would complicate bioengineering of the bypass and increase fish handling. Johnson et al. (1998) also recommend that surface bypass discharges not be dewatered for similar reasons.

The SBC and dewatering facilities would be built on the existing dams and would require extensive structural modification. Comparable volumes of flow have been dewatered at land-based systems such as irrigation canals to meet NMFS fish screen criteria. However, a large area of screen space would be required to meet these criteria. Available space for large screen systems may limit the volume of water that can be effectively screened at Lower Granite and other dams. Modeling studies to design a dewatering system have not been started yet, but could take 1 to 2 years to complete.

The location and design of the SBC outfall must also be carefully considered to ensure that juvenile fish safely enter the tailrace and quickly move downstream. Piaskowski et al. (1998) indicated that predation in the Lower Granite Dam tailrace will be limited by the presently low abundance of northern pikeminnow. However, they noted that predation in the tailrace could be significant if riverflow is low. Bennett and Naughton (1998) found low rates of predation on juvenile salmonids in 1996 and 1997 in the Lower Granite Dam tailrace. They thought that high flows, which were accompanied by lower water temperatures and higher turbidity, may have contributed to these low levels of predation.

The SBC outfall must also be designed and sited to avoid adverse impacts to fall chinook salmon spawning in dam tailraces. As previously noted, fall chinook salmon spawn in the tailraces of Lower Granite, Little Goose, and Ice Harbor dams. Dauble et al. (1999a) pointed out the potential effects of outfall construction and operation on fall chinook salmon spawning. Dauble et al. (1999b) reported that the number of redds declined in 1996 and 1997 after the juvenile bypass structures were modified in 1995 and 1996, although there was no direct evidence that work in the river affected adjacent spawning habitat. They also noted that gravel movement was documented in 1996 after high facility discharge and spilling occurred. The SBC discharges could affect fall chinook salmon spawning in the dam tailraces if they cause gravel movement or create undesirable current flow patterns or velocities.

Juvenile migration rates through the Snake River reservoirs and survival in the pools would not change with the installation of surface collection systems because the total volume of river flow would not differ from that under existing conditions. One of the main potential benefits of the SBC would be to reduce the delay of migrating juvenile salmonids in the forebays of the dams. Studies to date have shown varying effects of the SBC on passage through the forebay of Lower Granite Dam. Evans et al. (1999) reported that juvenile salmonid residence time in the forebay of Lower Granite Dam varied by run of fish and the route taken to pass the dam. Subyearling fall chinook, which migrate in summer, took longer than steelhead or spring chinook, which migrate in the spring. Steelhead took longer to pass the dam than spring chinook salmon, although their migration speed from point of release to the forebay was faster. Hatchery steelhead and spring chinook that passed via the spillway spent the least amount of time in the forebay. Wild steelhead that resided the shortest time in the forebay were those that passed through the turbines. Of the fall chinook that were monitored, those that passed through the SBC spent the least time in the forebay. Additional study would be necessary to verify these results.

Other operations under the Existing Systems Alternative would most likely continue with the Surface Bypass/Collector Alternative. In order to achieve high fish passage efficiencies, it is likely that the SBC would be used with spill and the existing screen and bypass system in operation. It should be noted that the original intent of the surface bypass concept was to provide a collection or bypass route that was more "normative" and less stressful on juvenile fish and not simply to collect more fish. Survival of juvenile salmonids that are collected by the existing system would be similar to that which is now observed. Therefore, additional effects of the Surface Bypass/Collector Alternative on anadromous fish would be similar to those described for the Existing Systems Alternative.

Surface bypass/collection has been proposed as a means of reducing spill and high TDG levels in the Snake River. Surface bypass/collection could reduce the volume of voluntary or controlled spill that now occurs during the fish migration season. However, the impacts of controlled spill which produces TDG levels of 120 percent or less have not been found to adversely affect migrating salmonids. Uncontrolled or involuntary spill during periods of high runoff or low electrical demand

can produce much higher levels of TDG that are lethal to fish. The period of peak spring runoff coincides with the time of high smolt migration.

Flow deflectors have been installed at the lower Snake River dams to reduce TDG levels. As presently designed, however, they cannot reduce TDG levels to the water quality standard of 110 percent. Under the SBC Alternative, TDG levels could be maintained at water quality standards or waivers with the installation of the SBC. During peak runoff when uncontrolled spill occurs, TDG levels would not be altered by this alternative unless additional structural measures are implemented.

8.1.2.1 Pacific Lamprey

It does not appear that the SBC would substantially improve passage conditions for migrating juvenile lamprey. Some improvement of downstream movement might be expected from the SBC since it could reduce the effect of impingement on the existing screen and bypass system. However, as was discussed in Section 6.1.4, juvenile lamprey screen systems do not extend deep enough to prevent juvenile lamprey from entering turbine intakes. Surface collectors, which do not draw from depths greater than the existing screen systems, may not be able to direct juvenile lamprey from turbine intakes. Reservoir impacts on migrating lamprey, which include slower migration rates through the impoundments and increased predation potential from northern pikeminnow and smallmouth bass, would be similar to those described for the Existing Systems alternative.

8.1.2.2 American Shad

Any effect of the SBC on American shad would depend on the design and the operational schedule of the system relative to outmigration of juvenile shad, which occurs in late fall and early winter.

8.2 Resident Fish (with Surface Bypass/Collector Alternative)

As with the Existing Systems Alternative, the Surface Bypass/Collection Alternative would have little effect on resident fish species. It is not likely that dam passage for white sturgeon would improve with this alternative. White sturgeon are benthic oriented and are not inclined to migrate downstream en masse.

8.2.1 Piscivore Predation on Juvenile Salmonids

Both the SBC and BGS structures may provide greater opportunities for predation by northern pikeminnow since they would divert and concentrate juvenile salmonids. Conversely, if juvenile salmonids are passed by the dams more efficiently (that is, faster and with less trauma), they would be less vulnerable to predation, especially by northern pikeminnow and channel catfish. This could be particularly important to the threatened fall chinook salmon, which migrate at smaller sizes and later in the year when water temperatures, and, therefore, predation rates, are higher. Predation studies are currently being conducted to determine if the SBC or BGS is increasing habitat or opportunities for predators.

8.3 Invertebrates (with Surface Bypass/Collector Alternative)

See Section 6.3.1, which details the potential impacts of future zebra mussel infestations.

8.4 Terrestrial Resources (with Surface Bypass/Collector Alternative)

The future with the Surface Bypass/Collection Alternative would be the same as that discussed above for the Existing Systems Alternative.

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9. Future with Natural River Drawdown Alternative

9.1 Anadromous Fish (with Natural River Drawdown Alternative)

The Natural River Drawdown Alternative would eventually restore the lower Snake River to a riverine condition. Dam breaching and drawdown would have short-term and long-term effects on anadromous salmonids. Short-term effects would occur during the actual dam breaching process and afterward, as the reservoirs are drawn down and sediments are flushed out. Short-term effects may be adverse to anadromous salmonids, but can be lessened by properly timing work activities, by providing measures to protect fish during construction, and by implementing fish salvage measures.

In the long term, dam breaching and drawdown would benefit all anadromous salmonids in the Snake River Basin. It is assumed that the natural, unaltered flow regime formed the ecosystem conditions necessary to produce abundant salmon populations (Vannote et al., 1980). Thus, on a river with extensive flow regulation, such as the Snake River, managing aspects of the flow regime to more closely resemble natural conditions, would improve salmon habitat conditions.

Drawdown would reestablish the continuum of riverine habitat that the Independent Scientific Group believes is essential to anadromous fish restoration. The major effects on anadromous fish would include restoration of spawning and rearing habitat for fall chinook salmon in the lower Snake River, improved migration conditions for juvenile salmonids and lamprey, and unimpeded upstream migration for adult salmonids, lamprey, and white sturgeon. Another major effect would be a significant reduction in mortality and injuries from fish that are now collected, go through turbines, or are bypassed in some other manner. This would also benefit resident fish that use the river as a migration corridor. The PATH group has estimated that natural river drawdown has the potential to about double the survival of juvenile salmonids during their migration through the lower Snake River (PATH, 1996). This increase in survival has the potential to rebuild anadromous fish stocks in the Snake River. Long-term effects would occur after riverine conditions are restored.

9.1.1 Construction and Short-Term Effects

Should the Natural River Drawdown Alternative be implemented, certain measures would be necessary to mitigate adverse impacts caused by removal of the earthen portion of the dam and lowering of the reservoir. Impacts of this alternative include increased turbidity, loss of fall chinook salmon spawning in dam tailraces, blockage of adult fish passage at the damsites, blockage of adult fish entry into Snake River tributaries, stranding of fish during drawdown, and loss of juvenile salmonids. NMFS is addressing these impacts in detail in the Technical Appendix A of the EIS for this study (Corps, 1999). The following is a summary of possible short-term impacts of the Natural River Drawdown Alternative.

9.1.1.1 Turbidity and Sedimentation Effects

Removal of the earthfill portions of the lower Snake River dams would increase turbidity and the amount of sediment suspended in the river during the mobilization and initial drawdown periods. Suspended sediment levels could be high during the initial period after dam breaching. The suspended sediment load in the Snake River is expected to be as high as 2,000 parts per million (ppm) immediately after breaching. The suspended sediments would likely include finer materials

such as silt, as well as coarser particles such as sands (T. Miller, Corps, personal communication). During the 1992 test drawdown of Lower Granite Reservoir, suspended sediment increased from a background level of 9.5 ppm to a high reading of 1,928 ppm. Most measurements were lower than 510 ppm, which was the second highest reading recorded. (IDFG, 1998)

High flows are expected to flush sediments out of the system down to the original riverbed within several years after the dams are breached and form a river channel flanked by higher areas of accumulated sediment. Hanrahan et al. (1998) indicate that fine sediments that have accumulated in Lower Granite Reservoir would be flushed out within 5 years after drawdown. Turbidity would decrease after the initial flushing of material, but would again temporarily increase during future high flow events. Additional sediment would be eroded from these higher areas and flushed out of the system with high flows until the streambanks become revegetated and the system stabilizes.

The high levels of suspended sediment immediately following dam breaching may impact anadromous fish by causing direct mortality. Waters (1995) noted that Lloyd (1987) reported fatal or lowered survival of fish from several unpublished studies where sediment concentrations were between 500 and 6,000 ppm. Sigler et al. (in Waters, 1995) reported some mortality of coho and steelhead fry at suspended sediment concentrations of 500 to 1,500 ppm. However, sockeye salmon showed no mortality when exposed to Fraser River sediment concentrations of 2,100 mg/L.(MacDonald and Newcomb, 1993). In other experiments, coho salmon exposed to the same Fraser River sediments experienced less than 50 percent mortality after 96 hours of testing. The direct effects on anadromous fish would depend on the time of year that dam breaching and the initial flushing of sediment occurred. Moderate levels of suspended sediment would reduce predation on juvenile salmonids by reducing their visibility to both birds and larger fish (Gray and Rondorf, 1986).

Resuspended sediments that resettle downstream may adversely affect any existing fall chinook redds that are present in the tailraces of Lower Granite, Little Goose, and Lower Monumental dams by filling the spaces between gravels and cobbles. This would prevent water flow through the redd and reduce the flow of oxygen to incubating eggs. Fine sediment may suffocate any embryos and fry within the redds and also could prevent fry emergence. Resuspension of toxic materials is discussed in the contaminants section of this report.

Impacts on anadromous fish would be minimized if dam breaching were conducted during the winter when the smallest number of anadromous fish are present. Adult steelhead that spend the winter in the Snake River reservoirs and incubating fall chinook salmon in redds in dam tailraces would be most affected if work was conducted during the winter. Work during other times of the year would have a much greater effect on all species and stocks of migrating juvenile and adult salmonids.

9.1.1.2 Effects on Fall Chinook Salmon Spawning in Dam Tailraces

Limited fall chinook spawning has been documented in the tailraces of Lower Granite and Little Goose dams where up to 20 redds were estimated to have been present in 1993 (Dauble et al., 1995). Tailrace spawning has since declined to five redds in 1996 and 1997 (Dauble et al., 1999b). Spawning is also thought to occur in the Lower Monumental Dam tailrace based on findings of eggs and fry when that area was dredged in 1992. However, no redds have been seen during surveys made in following years. At Lower Granite and Little Goose dams, spawning presently occurs only near the juvenile fish bypass outfalls (Dauble et al., 1994).

Drawdown could impact fall chinook spawning at these sites by preventing spawning during actual drawdown operations, by covering existing redds with sediment, by physically shifting spawning

substrate, or by altering water velocities at known spawning sites. The Corps is presently studying simultaneous removal of all four dams as the primary option for the Natural River Drawdown Alternative. Removal of two dams at a time (for example, Lower Granite and Little Goose or Lower Monumental and Ice Harbor) over a 2-year period is also being considered. As presently being studied, dismantling of the projects would take from 60 to 90 days from the start of excavation to the time the reservoirs are drawn down to streambed level. The Corps proposes that this work would start in August and be completed by December or January (Raytheon Infrastructure Inc., 1998). Work is proposed for completion by January to avoid the period when the risk of river flooding increases. According to this schedule, drawdown work would occur during the adult migration and spawning period for fall chinook salmon. Such activity would likely preclude fall chinook spawning. Scheduling of drawdown work for the winter would allow fall chinook to spawn in the dam tailraces, but redds and juvenile fish could be impacted by sediment deposition or high concentrations of suspended sediments. The impact of the short-term loss of tailrace spawning would be small compared to the overall benefit to the Snake River fall chinook population that is expected to result from drawdown.

9.1.1.3 Blockage of Adult Fish Passage at the Damsites

As stated in Section 3.3, drawdown work is proposed to begin in August and continue for 60 to 90 days. This is the period of peak migration for adult steelhead and fall chinook salmon in the lower Snake River (September through November). Work during the migration period would affect upstream migration and passage at the dams. Blockage of fish passage would affect steelhead and fall chinook that use the Tucannon River System and those returning to Lyons Ferry Hatchery as well as those bound for the mainstem Snake River and its tributaries upstream of Lower Granite Dam.

9.1.1.4 Blockage of Adult Fish Entry into Snake River Tributaries

Sediment has accumulated and formed deltas where tributaries enter the lower Snake River reservoirs. During drawdown, these deltas would impede upstream fish passage until the streams can remove sediment down to the original streambed elevation. Schuck (1992) observed a large deposit of sediment at the mouth of Alpowa Creek during the 1992 drawdown test of Lower Granite Reservoir and noted a vertical drop at the mouth of this stream that would have been impassable to steelhead. This is likely to be a temporary barrier that would erode rapidly down to the river elevation. Cunningham (1993) reported erosion of deltas at the mouths of tributary streams throughout Lower Granite Reservoir during the 1992 drawdown test. He noted that a channel measuring 3.7 m (12 feet) deep and 12.2 m (40 feet) wide eroded through the delta of Alpowa Creek during the 1992 drawdown test. Observations made during a test drawdown of Lake Mills on the Elwha River showed that erosion of delta sediments consisting of sand, gravel, and cobble occurred rapidly (T. Randall, BOR, personal communication). Tributary stream deltas should be monitored for potential blockages to migration during drawdown. Any blockages to migration could be addressed by collecting and transporting fish around obstructions.

The Corps is presently studying installation of a water temperature control structure at Cougar Dam on the South Fork McKenzie River in the Willamette River Basin. Installation of this structure would require a 3- or 4-year drawdown of Cougar Reservoir to natural river level. This would provide a rare opportunity to study the effects of downstream sediment transport since drawdowns of this magnitude and duration are uncommon. We recommend that the Corps study the sedimentation issue at Cougar Reservoir since it may be applicable to the lower Snake River natural river drawdown analysis and to all of the facilities that are operated by the Corps in the region.

9.1.1.5 Stranding of Fish During Drawdown

Drawdown may also strand fish if water recedes rapidly and fish become trapped on low gradient flats or in isolated pools. Fishery agencies monitored the 1992 drawdown of Lower Granite Reservoir and observed that only small numbers of anadromous fish were affected (USFWS, 1994). Schuck (1992) noted that small numbers of wild and hatchery steelhead and wild chinook were found in backwaters during monitoring of the 1992 drawdown operation, although large numbers of juvenile resident fish had died. Timing of the drawdown to occur during times when few juvenile salmonids would be present and controlling the rate at which the water level is drawn down would reduce adverse stranding impacts.

9.1.1.6 Loss of Juvenile Salmonids

Much of the drawdown work would occur when relatively few juvenile salmonids are normally present in the reservoirs. Impacts to juvenile salmonids would be minimized by conducting those activities that have the most detrimental short-term impacts when the fewest fish are present. Average juvenile fish passage indices at Lower Granite Dam from 1985 to 1997 indicate that relatively few yearling chinook, coho, or steelhead pass that site after early August. However, subyearling chinook and sockeye salmon continue to pass Lower Granite Dam into late November. The fewest juvenile salmonids would be affected if drawdown operations were conducted in mid-winter. Based on observations at Lower Granite Dam, the period when the fewest juvenile salmonids would be present is in the late fall and early winter months from December through February. Final drawdown work should be conducted as late into the fall/winter season as possible to minimize adverse impacts on juvenile anadromous salmonids.

9.1.2 Long-term Effects

Detailed analysis and modeling of the long-term effects of the Natural River Drawdown Alternative are being conducted by the PATH group. This analysis is now being conducted and results will be available in the future. The results of the PATH analysis and modeling efforts will be incorporated into the final FWCAR. The following is a qualitative summary of expected long-term effects of the Natural River Drawdown Alternative on anadromous salmonids.

9.1.2.1 Spawning Habitat

Restoration of the lower Snake River to a riverine condition would likely reestablish suitable spawning habitat for fall chinook salmon in the reach of river from the head of Lower Granite Reservoir to Ice Harbor Dam. It is likely that fall chinook spawning would occur in the lower Snake River after drawdown and riverine conditions are restored provided that (1) suitable substrates become available; (2) suitable temperatures occur during the known spawning time of Snake River fall chinook; and (3) adequate streamflows are available to provide sufficient current velocities. Before inundation, the lower Snake River included a series of pools, riffles, and rapids. Islands and side channels were present at numerous locations. A review of survey maps from 1917 shows that the Snake River was a dynamic alluvial river system that had diverse habitats such as spawning, rearing, and adult staging areas. Fall chinook salmon spawning reportedly occurred in the lower Snake River before construction of the lower river dams (NMFS and USFWS, 1972; Fulton, 1968).

The USGS Biological Resources Division's CRRL conducted a study for the USFWS to determine the potential fall chinook spawning and rearing habitat that could result from the Natural River Drawdown alternative. The CRRL study has determined that about 1,437 ha (3,550 acres) of

potential suitable spawning habitat would be available after drawdown. This study was based on existing survey information collected before the Snake River dams were built, spawning habitat criteria for water depth, mean water column velocities, and substrate composition that have been found to be suitable for Snake River fall chinook salmon, and river flow modeling done by the Battelle Pacific Northwest National Laboratory (PNNL). The methodology used to derive this estimate is summarized in Annex C. Table 9-1 indicates the maximum area of potential fall chinook spawning habitat, unsuitable spawning area, and area of unknown value for spawning by river reach in the lower Snake River. Figure 9-1 shows an example of potential fall chinook salmon spawning area for a reach of river now inundated by Ice Harbor reservoir. Complete maps of potential spawning habitat for the entire reach of the lower Snake River are available from the Corps' Internet site and from the CRRL and USFWS.

Table 9-1. Estimated Amount of Habitat Suitable for Fall Chinook Spawning Under Natural River Conditions[1/]

	Confluence to IHR	IHR	LMN	LGO	LGR	Total
Not Suitable	1,243	1,986	1,245	2,999	2,532	10,004
Suitable	642	1,078	1,294	457	76	3,547
Unknown	68	410	641	298	134	1,550
Total	**1,952**	**3,475**	**3,179**	**3,753**	**2,742**	**15,101**

1/ Suitable habitat is defined as those areas having water depths between 1.3 and 21 ft, mean column water velocities between 1.3 and 6.4 ft/s, and substrates classified as cobble, gravel, cobble-gravel, gravel-cobble, or cobble-sand. Units are in acres.

It is likely that fall chinook salmon would spawn in the lower Snake River after finer sediments that have accumulated in the reservoirs are removed, the former riverbed is reexposed, and gravels are redistributed or flushed of fine materials. The length of time or river discharge that would be needed to reestablish suitable spawning substrate for fall chinook salmon spawning is presently unknown. As noted previously, the Lower Granite reach of the lower Snake River would be flushed of fine sediments within 5 years. Observations of a test drawdown of Lake Mills, a reservoir on the Elwha River in Washington, showed that erosion of exposed sediments occurred rapidly. Modeling of streamflows based on historic records of high, medium, and low flow years indicated that the Elwha River would reform a river channel in about three years (T. Randall, BOR, personal communication).

Establishment or expansion of spawning populations of fall chinook salmon elsewhere in the Columbia River Basin in recent years indicates that they will use suitable habitat when it becomes available and when adult fish return in adequate numbers. Spawning populations of fall chinook have remained stable, increased, or become established at several locations in the Columbia River Basin. These include populations in the Hanford Reach of the Columbia River, the Columbia River in the Pierce/Ives Island area just downstream from Bonneville Dam, the lower Deschutes River, Hell's Canyon, and the Clearwater River.

One example of a population that has maintained itself is the Hanford Reach group of upriver bright fall chinook in the free-flowing section of the Columbia River. The Independent Science Group (ISG, 1996) has highlighted the contrast between the spawning populations of fall chinook salmon in the Hanford Reach of the Columbia River and the Snake River downstream from Hells Canyon Dam.

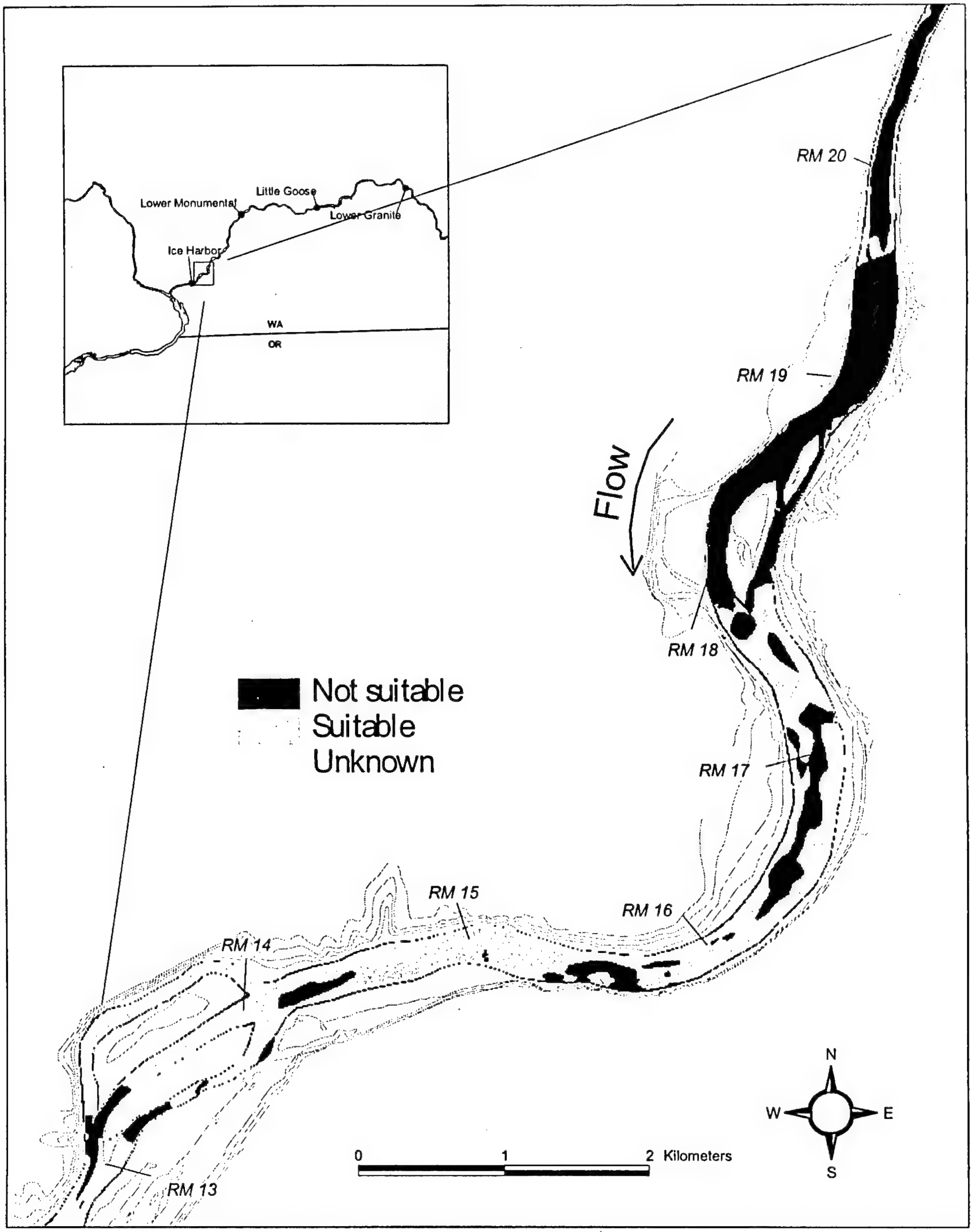

Figure 9-1. Example of Projected Habitat Suitable for Fall Chinook Spawning Under Natural River Conditions

The Hanford Reach fall chinook population has increased substantially, while the Snake River population has declined to the point where listing under the ESA was warranted. Spawning escapement of adult fall chinook to the Hanford Reach has ranged from about 14,000 in 1981 to 105,000 in 1986 and averaged about 40,000 from 1964 to 1991 (Langness et al., 1998). The Snake River fall chinook population has been reduced to the point that available spawning habitat exceeds the number of returning adult fish available to utilize it (Connor et al., 1994).

The major difference in conditions encountered by Hanford Reach and Snake River fall chinook appears to be upstream from the confluence of the Snake and Columbia rivers since both populations pass through the lower Columbia River and its four mainstem dams. The most obvious difference between the Hanford Reach and the lower Snake River is the presence of the four dams and reservoirs. There are several potential causes for the difference in success between Hanford Reach and Snake River fall chinook salmon that were related to the presence or absence of dams and reservoirs. These include differences in survival during juvenile migration, differences in rearing habitat, predation, delay in juvenile migration through the Snake River dam and reservoir system, and water temperature.

Hanford Reach and Snake River fall chinook emerge and begin their downstream migrations at about the same time (W. Connor, USFWS, fishery biologist, personal communication). Delay in passing through the lower Snake River reservoirs appears to be a primary difference between the two stocks of fish. Hanford Reach subyearling fall chinook now reach McNary Reservoir at about the same time Snake River fish arrive at Lower Granite Reservoir. Delayed passage through the Snake River reservoirs results in Snake River migrants arriving at McNary Reservoir later than Hanford Reach fish. In addition, loss to predation also occurs in the Snake River pools. The ISG discussed differences in suitable habitats for rearing and migration for subyearling fall chinook salmon as a possible cause for the difference in success of the two populations. Hanford Reach habitat consists of flooded cobble shallows and riparian vegetation which provide abundant insect life, while Snake River reservoirs consist of eroding soil banks and riprap which are poor habitats for producing insect food items for subyearling chinook.

Another population of upriver bright fall chinook salmon has become established within the past decade in the Pierce/Ives Island reach of the Lower Columbia River downstream from Bonneville Dam. This population has established itself in suitable habitat evidently from fish that originated from hatchery programs. WDFW has conducted a genetic analysis of fish from this population and determined that they are most closely related to upper Columbia River bright stocks (Marshall, 1998). Spawning has occurred in substrates and at velocities similar to those where spawning has been observed at other locations in the Columbia and Snake rivers.

Fall chinook spawning has also been reestablished in the lower Clearwater River and has been increasing in recent years (B. Arnsberg, Nez Perce Tribe, personal communication). Fall chinook salmon now spawn in the lower 72 km (45 miles) of the lower Clearwater River (Groves and Chandler, *in press*).

The run of Deschutes River fall chinook salmon is another example of a population that has increased. This population has increased and has averaged about 6,000 fish annually from 1990 to 1996 (Myers et al., 1998). Returns of fall chinook salmon to the Deschutes River increased to nearly 21,000 in 1997 and was over 11,000 in 1998 (ODFW, unpublished). Deschutes River fall chinook salmon are also now considered to be part of the same population as Snake River fall chinook. NMFS initially determined that Deschutes River fall chinook were within the evolutionarily significant unit (ESU) for Snake River fall chinook salmon (Myers et al., 1998). This determination

was based on genetic, life history, and ecological similarities and differences of chinook salmon. The Deschutes River population was recently placed into a new ESU that does not warrant ESA protection. Recent returns of Fall chinook salmon to the Deschutes River have averaged about 16,000 fish, increasing at about 18 percent annually (NMFS, 1999).

Historically, the Snake River is thought to have produced the greater portion of this population compared to the Deschutes River. The Snake River spawning population is estimated to have been about 72,000 during the 1930s and 1940s, while the Deschutes River population was much smaller. The situation has changed to the point where the Deschutes River natural spawning population of about 6,000 fish is far larger than the Snake River natural spawning population of about 500 (Myers et al., 1998)

Snake River fall chinook salmon have been observed spawning in areas with characteristics similar to those used by fall chinook for spawning elsewhere in the Columbia River System. Connor, et al. (1993) found fall chinook salmon spawning in areas with physical characteristics typical of spawning sites used by fall chinook in other reaches of the Columbia River. Snake River fall chinook have been reported to use substrates ranging from 2.5 to 15.2 cm (1 to 6 inches) in diameter for spawning. They have also been observed spawning at depths ranging from 0.4 to 6.5 m (1.3 to 21 feet) deep. The preferred current velocity for spawning has been found to range from 0.4 to 2.0 m (1.3 to 6.4 feet) per second (Connor, et al., 1994; Groves and Chandler, *in press*).

Snake River fall chinook typically spawn from late October to mid-December as water temperatures decline. Most spawning occurs from late October through November. In recent years, spawning in the Hells Canyon reach of the Snake River has started as temperatures dropped to about 14°C (57°F) and ended as temperatures reached about 5°C (41°F) (A. Garcia, USFWS, fishery biologist, personal communication).

Monitoring of potential fall chinook salmon spawning sites would be necessary to determine the suitability of gravels and cobbles, water velocities over these sites at known river flows, water flow through potential spawning gravels, and water temperatures during the time of expected fall chinook spawning. Control of river flows and temperatures by releases of water from Dworshak and/or Brownlee dams could be used to provide suitable conditions for fall chinook spawning and incubation.

Fall chinook that originate from upstream locations in the Snake River Basin may naturally establish the spawning population in the restored river reach or fish from other sources, such as the Hanford Reach or Priest Rapids Hatchery, may colonize it. Establishment of the spawning population from Snake River fall chinook stock is essential to maintain the genetic integrity of this population. Supplementation of fish from Lyons Ferry Hatchery, which are included in the ESU for the Snake River, may be possible to establish a spawning population in the lower Snake River.

Spawning time of fall chinook salmon could change if water is cooled to a suitable temperature sooner under the Natural River Drawdown Alternative. Water temperature modeling conducted for the overall feasibility study indicates that dam breaching would produce a dramatic change in the volume and heat storage capacity of open water in the lower Snake River (Corps, 1999). Maximum temperatures would be higher in the summer during low flow years, but the river would cool faster in the fall compared to the other Alternatives. Modeling predicted that water temperatures would drop to 15°C (59°F), at the end of the summer about 15 days earlier than in 1994, a low water year. In 1997, a high water year, the drop to 15°C (59°F) was predicted to occur 5 days earlier. As noted above, Garcia reported fall chinook spawning begins in the Snake River when water temperature declines to 14°C (57.2°F).

Drawdown could improve migration conditions for adult fall chinook by lowering river temperatures in the summer if combined with water temperature control. In low water years, warm water temperatures in the late summer may stress adult fish in the Snake River. Releases of cool water from Dworshak Reservoir are used to lower water temperatures, but this effect is dissipated by warm water in the reservoirs. Restoration of a riverine condition could provide a greater and faster cooling effect from Dworshak Reservoir releases.

Optimum flows for fall chinook salmon spawning would have to be determined after suitable spawning substrate becomes established since the locations of spawning sites cannot be predicted. Instream flow studies should be conducted to determine the optimum flow conditions for fall chinook salmon spawning, incubation, rearing. Without such information, we would recommend that an interim flow that is near the flow that existed before construction of the Snake River dam and reservoir system be provided. Determination of this flow may be difficult because of the extensive water development facility system in the Snake River Basin. Flows in the lower Snake River during the fall chinook spawning period are also controlled by water that is released from the Hells Canyon hydroelectric complex and from Dworshak Dam.

9.1.2.2 Juvenile Fish Migration

Juvenile salmonid migration through the lower Snake River is presently much slower than it was under free flowing river conditions before the dams were built. Breaching of the dams would restore the Snake River to a free flowing condition and conditions for migrating juvenile salmonids would be similar to the pre-dam situation. The Natural River Drawdown Alternative would result in a return to riverine conditions in the lower Snake River. One of the major results of restoring the lower Snake River to riverine conditions would be faster travel by juvenile salmonids though this reach of river to the Columbia River. Faster migration rates would occur with or without flow augmentation. Downstream migration rates would be similar to those for fish in the Hells Canyon Dam to the head of Lower Granite Reservoir.

Passage delays in the reservoirs and at the four lower Snake River dams would be eliminated by breaching the dams. Direct observations of radio-tagged wild and hatchery juvenile steelhead showed that their migration rates in the free-flowing reach of the Snake River (from tributary release sites to Asotin at the head of Lower Granite Reservoir) ranged from 3.4 to 5.1 km/hr (2.1 to 3.2 miles/hr). Migration rates in Lower Granite Reservoir ranged between 1.5 and 1.8 km/hr (0.9 and 1.1 miles/hr) (Adams, et al., 1998). Natural subyearling chinook salmon that were PIT-tagged in the vicinity of river mile 215 in Snake River from 1995 to 1997 took an average of 42 days to pass Lower Granite Dam compared to an average of 41 days for fish that were PIT-tagged and released 81 km (50 miles) downstream (W.P. Connor, USFWS, unpublished data). Fish released upstream probably traveled the 81 km (50 miles) of free-flowing river between the release sites in one day. For comparison, Smith et al. (1997a) reported that it took PIT-tagged hatchery subyearling fall chinook salmon an average of six days to pass through the 60 km (38 miles) of Little Goose Reservoir and by Little Goose Dam. From the above information, it could take up to 22 days for fish to pass through the four Snake River reservoirs compared to only three days if the four lower Snake River dams were breached.

Water travel time from the Clearwater-Snake River confluence to the Columbia-Snake River confluence would be drastically reduced under the Natural River Drawdown Alternative compared to the existing full pool condition. Table 9-2 compares water travel time between a free flow and full pool condition at various river discharges.

Survival of subyearling fall chinook is likely to be higher than that which is now observed when fish pass through the existing reservoir and dam system. Recent survival estimates for hatchery fall chinook salmon in the free-flowing reach of the Snake River developed by Muir and Peterson (1998) indicate the survival per kilometer for the reach from Pittsburg Landing (within Hells Canyon) to Billy Creek (near the head of Lower Granite Reservoir) was about 0.999 during 1995 and 1997 studies.

Table 9-2. Juvenile Salmonid Travel Times on the Lower Snake River from Lewiston, Idaho to the Mouth[1/]

Discharge (cubic feet per second)	Free Flow Travel Time in Hours	Full Pool Travel Time in Hours
180,000	26	110
118,000	30	175
60,000	40	350
40,000	48	525
25,000	62	825
20,000	72	955

1/ Data from Corps (1994).

9.1.2.3 Rearing and Migration of Juvenile Fall Chinook Salmon

Approximately 224 km (139 miles) of riverine habitat would be restored for juvenile rearing. Fall chinook salmon evolved to rear in riverine habitat. Available information indicates that river-reared parr survive at higher rates than reservoir-reared fish. Smith et al. (1997b) released PIT-tagged subyearling chinook salmon parr in the Snake River at river mile 217 and river mile 166. The parr released at river mile 217 reared primarily in the river, while the fish released at river mile 166 reared primarily in Lower Granite Reservoir. Smolt survival was equal between the above two treatments since fish were released on the same dates and passed Lower Granite Dam over similar time periods. Mortality per kilometer calculated for the time period between release and passage by Lower Granite Dam was almost twice as high for reservoir-reared fish (3.9 percent/km) than for river-reared fish (2.1 percent/km). Lower survival of reservoir-reared fish was because of the unnatural rearing conditions in Lower Granite Reservoir. Breaching the four lower Snake River facilities would probably improve rearing conditions and the survival of fall chinook salmon parr in the lower 224 km (139 miles) of the Snake River.

The USGS CRRL has analyzed potential suitable rearing habitat for fall chinook salmon under Natural River Drawdown conditions for the USFWS and estimated that about 312 ha (770 acres) of suitable rearing habitat would be restored in the lower Snake River. It also estimated that about 257 km (160 miles) of suitable rearing habitat along the shoreline would become available under Natural River Drawdown conditions. Annex C describes the methodology used to derive these estimates. Tables 9-3 and 9-4 show the areas of rearing habitat and lengths of shoreline habitat for the lower Snake River that would result from the Natural River Drawdown.

Table 9-3. Estimated Area of Suitable Fall Chinook Rearing Habitat under Natural River Drawdown Conditions[1/]

	Confluence to IHR	IHR	LMN	LGO	LGR	TOTAL
Suitable	67	170	201	216	113	767
Not Suitable	1,921	3,304	2,991	3,537	2,629	14,383
Total	1,988	3,475	3,191	3,754	2,742	15,150

1/ Suitable, or preferred, rearing habitat is defined as those areas where the likelihood of encountering 10 or more fish at a shock location is greater than 50 percent. This likelihood was calculated by means of a discriminate analysis based on data collected for rearing fall chinook on the free-flowing Hanford Reach of the Columbia River, Washington (Loreley Key, USGS, unpublished method). The environmental variables considered were water depth, mean water column velocity, and distance to the nearest shore. The areas analyzed were limited to those falling within 81.7 feet of shore, having water depths of 0.3 to 5.3 feet, and having mean water column velocities less than 4.0 feet/s, since fish were not encountered outside of these ranges in the Hanford Reach. Substrate was excluded due to the coarseness of the data available for the lower Snake River. The units are in acres.

Table 9-4. Estimated Length of Shoreline Suitable for Fall Chinook Rearing under Natural River Drawdown Conditions[1/]

	Confluence to IHR	IHR	LMN	LGO	LGR	TOTAL
Suitable	15.2	35.3	38.8	46.0	24.7	160.0
Not Suitable	13.3	55.8	36.9	56.4	58.0	220.3
Total	28.4	91.1	75.7	102.4	82.7	380.3

1/ The values below describe the total length of shoreline that borders habitat suitable for rearing as described above. Shoreline includes that of islands. Due to the resolution of the data, only habitat segments longer than 30 feet were identified. Units are in miles.

Juvenile salmonids would not be subjected to the extremely high levels of TDG that can be produced during times of uncontrolled spill at the lower Snake River dams. For example, TDG levels were above 120 percent during much of the spring and early summer in 1996 and 1997 and exceeded 130 percent at times. Hells Canyon and Dworshak dams may also produce high TDG levels during times of uncontrolled spill. Riverine conditions in the lower Snake River would help to dissipate the high TDG levels produced by Dworshak and Hells Canyon dams. Data for the Hells Canyon reach show that TDG dissipated from nearly 126 percent to 110 percent in about 48 km (30 river miles) of river and from about 121 percent to 110 percent in about 72 km (45 miles) at spills of 13,400 cfs and 21,000 cfs, respectively (Idaho Power Company, unpublished data).

Predation effects are discussed in detail in Section 5.2.3 of this report. In general, predation upon juvenile salmonids would be reduced under the Natural River Drawdown Alternative. Juvenile salmonids would move through the lower Snake River at a faster rate and be exposed to predators for a shorter time. Population densities of predators would also decline under riverine conditions as habitat conditions they prefer are reduced. The lower Snake River would also remain more turbid under riverine conditions during the spring migration period since sediment would not settle out in reservoirs. The loss of juvenile salmonids to predators has been found to be lower in turbid water than in clearer water (Gregory and Levings, 1998).

Aquatic invertebrates that now inhabit the reservoirs would be replaced by those found in a riverine environment. Juvenile salmonids, particularly subyearling fall chinook, would feed upon these organisms. With drawdown, more riparian vegetation would become established. This would increase the production of terrestrial insects. Return to a riverine condition would leave a more complex environment of pools, riffles, and rapids. This would provide a greater diversity of aquatic invertebrates and possibly abundance of food items.

Food habits of juvenile salmonids would change from those based on a reservoir system to those more typical of a riverine system. Before impoundment by Lower Granite Reservoir, the main aquatic invertebrates in that reach of the Snake River were mayflies and caddisflies (Edwards and Funk, 1974 in Curet, 1993). In the remaining free-flowing reach of the Snake River, fall chinook salmon have been found to feed primarily on mayflies, midges, and caddisflies. Terrestrial insects were found to compose three times the number and four times the biomass of food items eaten by subyearling fall chinook compared to aquatic organisms (K. Tiffan, USGS, CRRL, personal communication). Rondorf et al. (1990) reported that caddisflies that were eaten by subyearling fall chinook in the free-flowing reach of the Columbia River provided from 80 to 160 times the energy content of individual daphnia (waterfleas) that were consumed by these fish in reservoirs. Daphnia were the major aquatic organism eaten in McNary Reservoir.

9.1.2.4 Adult Fish Migration

Before construction of the lower Snake River dams, chinook salmon migrated upstream at rates of 20 to 24 km (12.4 to 14.9 miles) per day, steelhead moved at rates of 10 to 16 km (6.2 to 9.9 miles) per day, and sockeye salmon migrated at rates of 19 km (11.8 miles) per day (Bjornn and Peery, 1992). Since the impoundment of the lower Snake River adult salmonid migration has been altered. Adult fish passage has been delayed at dams, some fish have fallen back over the dams after initially passing them, fish have been exposed to high levels of TDG during times of uncontrolled spill, and some fish have suffered physical injury such as head burns.

Breaching of the four lower Snake River dams would allow unimpeded upstream migration of adult salmonids to spawning areas in the mainstem river and tributaries. Migration rates and conditions would be similar to those that existed before the dams were constructed, and the river was impounded. Adult salmonids would not be subject to delay or fallback during passage at any dams. Fish would also not be exposed to the high levels of TDG that now occur during periods of uncontrolled spill. Head burns and other physical injuries that occur at dams would be eliminated.

Fish passage structures would be placed in the new river channel at the dam breach sites to ensure that adult salmonids would be able to pass these areas. Precast concrete blocks are presently proposed to be placed along the shoreline to create zones of slower velocity (Raytheon Infrastructure, Inc., 1998). These structures would be installed wherever the river velocity is greater than 1.5 m (5 feet) per second so that fish passage velocity criteria could be met. This would allow fish to rest while passing the dam breach sites. The structures would be designed to enable fish passage at a maximum flow of 170 kcfs. They would also be designed to withstand a river flow of up to 420 kcfs.

9.1.2.5 Drawdown with Flow Augmentation

The biological benefits resulting from restoration of riverine conditions in the lower Snake River could offset the need for flow augmentation during the spring migration period. Summer flow augmentation for fall chinook may not be needed if the net benefit of natural river conditions is greater than the loss resulting from reduced flows in the lower Columbia River. Restoration of

natural river conditions in the lower Snake River may also allow more juvenile fall chinook to migrate during their historical period near the end of the spring freshet rather than during the low flows and high temperatures of summer.

However, the overall study will also examine potential flow augmentation with the Natural River Drawdown Alternative. Presently, PATH has been directed to examine only the Natural River Drawdown with NMFS Biological Opinion flows. Implementation of the Biological Opinion flows is discussed in detail in Section 6.1.2.2 of this report. The effects of the Natural River Drawdown alternative with flow augmentation under the NMFS Biological Opinion will be addressed in detail through the PATH process. Generally, NMFS Biological Opinion flow augmentation with the Natural River Drawdown Alternative should improve habitat conditions for juvenile and adult anadromous salmonids compared to a situation without flow augmentation. Flow augmentation should decrease the time required for juvenile salmonids to travel through the Snake River to the Columbia River. Conditions for adult salmonid migration should be improved by the additional water that is provided during the summer.

Streamflow augmentation using water from Dworshak and Brownlee reservoirs has been used to increase the downstream migration rate of juvenile salmonids through the lower Snake River reservoirs. It may also be used as a tool to aid the migrations of adult and juvenile fish and spawning of fall chinook salmon under the natural river drawdown condition. Although natural river drawdown would likely increase the rate at which juvenile salmonids pass through the lower Snake River to the Columbia River, flow augmentation may benefit juvenile migrants in dry years when river flows would be low or during the summer migration period when flows typically decline and water temperatures increase.

Flow augmentation using cooler water from Dworshak Reservoir has also been used to improve the survival of summer migrants such as subyearling fall chinook and sockeye salmon during their passage through the lower Snake River reservoirs. Flow augmentation with temperature control may increase the survival of subyearling fall chinook and sockeye during their downstream migration through the free-flowing Snake River after drawdown.

Natural River Drawdown would increase the survival of juvenile anadromous salmonids in the Snake River. However, these fish would still have to pass the four lower Columbia River dams and reservoirs: McNary, John Day, The Dalles, and Bonneville. The NMFS 1995 Biological Opinion and 1998 Supplemental Biological Opinion have established spring and summer flow targets for the Columbia River at McNary Dam to improve juvenile fish survival during their passage through the lower Columbia River. Snake River summer flow needs could be met by providing adequate flow from Dworshak and Brownlee reservoirs to help meet the flow target at McNary Dam. The summer flow target is 200 kcfs from July 1 through August 31. This flow would benefit juvenile salmonids from the Snake River, as well as those from the Columbia River as they migrate through the lower Columbia River reservoirs.

9.1.3 Pacific Lamprey

Drawdown and/or removal of facilities on the mainstem Columbia or Snake rivers would have a positive effect on recovery of lamprey production by providing free passage and access to historical spawning and rearing habitat. Survival of juvenile lamprey during downstream passage should be increased because injury and mortality caused by fish screens or turbines would be eliminated. Passage and survival of adult and juvenile lamprey would improve. Due to other circumstances limiting lamprey production, it is unknown whether this action would be beneficial.

9.1.4 American Shad

Drawdown and/or removal of any of the mainstem facilities, either in the Columbia River or the Snake River, would reduce shad production by eliminating spawning and rearing habitat. Over time, production of shad in this section of the Snake River would probably revert to whatever pre-dam levels might have been. It should be noted that overall production of shad in the Columbia River Basin would not be affected by natural river drawdown in the Snake River.

9.2 Resident Fish (with Natural River Drawdown Alternative)

Response of the resident fish community to natural river drawdown would depend on several things: timing and duration of the drawdown, amount of time required for flushing of the sediment loads which have built up since the dams were closed, and response of the habitat and prey base. Of particular importance will be the amount of time required to stabilize the recreated riverine habitat. As the habitat stabilizes, resident fish species will begin recovering from the initial impacts of the construction phase of dam removal.

9.2.1 Construction Effects

The initial drawdown has the potential to cause several effects. Depending on timing of the drawdown, if eggs and nests are left dewatered, spawning success of many non-native species could be heavily impacted. Lowered water levels could leave large quantities of fish stranded in backwater and embayment areas. Temporary large increases in sediment load could lead to decreased water quality to the point of causing harm (abraded and clogged gills), which, if severe enough or continued over a long-enough time, could lead to increases in mortality. Other potential effects include loss of habitat and cover and decreased food abundance.

During the March 1992 Drawdown Test of Lower Granite and Little Goose reservoirs, overall effects to resident fish were minimal (Schuck, 1992). Many embayments formed by county or state roads or railroad grades drained through culverts, with the fish populations following the flow. Despite this, thousands of resident fish were stranded in backwater areas and embayments (Schuck 1992, Corps, 1993). By far, most of these were juvenile fish (Schuck, 1992). Brown bullhead (67 percent) and crappie sp. (13 percent) made up the majority of the estimated mortality. Other resident species also stranded by the test drawdown included smallmouth bass, largemouth bass, bluegill, yellow perch, pumpkinseed, northern pikeminnow, carp, redside shiners, and other non-game species. This loss, however, was insignificant compared to overall numbers of fish in the reservoirs (USFWS, 1993b).

Adult mortality was far less extensive than juvenile fish mortality. The majority of adult fish found stranded were largemouth bass. Because these fish were relatively rare in Lower Granite and Little Goose reservoirs to begin with, probably the most serious impact of the drawdown to resident fish was to largemouth bass (Schuck, 1992).

9.2.1.1 Native Species

The initial drawdown would have minimal effects on native resident species. Native species tend to spawn in moving water habitats, such as the tailwater areas and tributaries of the reservoirs. Therefore, spawning success would not be affected. As drawdown occurs, most adult and juvenile native fish would be able to follow the receding water level (proposed at about 0.6 m/day [2 feet/day]). However, young-of-the-year native fish would have a more difficult time avoiding becoming stranded. They use the shallow, warmer areas of the reservoirs for rearing and their small size renders them less mobile. Consequently, they are more vulnerable to fluctuating water levels.

9.2.1.2 Non-native Species

Non-native species would suffer more from the initial drawdown than the native species. The majority of non-native species require shallow water with zero to low velocities for spawning and rearing success. These areas would be dewatered. However, spawning for most non-native resident species would either be completed or nearly so by August, the proposed initiation of drawdown (Figure 9-2). Therefore, the potential to desiccate eggs and nests is very minimal.

Adults and juveniles of these species would also be able to follow receding water levels in most cases. However, as with the drawdown test, many young-of-the-year and juvenile fish would be stranded in embayments and backwater areas. If drawdown is initiated during the winter (as proposed), stranding effects will be minimized. Young-of-the year will have a full season's growth and be better able to follow receding water levels. Both adults and juveniles in embayments isolated from the main body of water would be stranded as water leaves these basins.

Most non-native species would be completely displaced from their preferred habitat. Although new shallow habitat will be formed, there would be a delay before appropriate vegetation, substrate, and possibly food base would be developed. Lowered growth rates could lead to lower over-winter survival for young-of-the-year fish not subjected to stranding. Spawning the following spring would be severely impacted due to the shifting, unstable substrate.

9.2.2 Long-term Effects

Generally, returning the lower Snake River to a riverine environment would benefit native species which evolved to thrive in that type of habitat. Non-native species, most of which prefer more lacustrine, or lake-like conditions, would decrease in abundance.

9.2.2.1 Expected Habitat Changes

In order to assess expected habitat changes from breaching the four dams on the lower Snake River, we assume habitat characteristics will be very similar to what existed prior to dam construction. Data collected in 1934 and 1935 along transects of the Snake River was used to predict future river conditions (Neitzel et al., 1998). This data was digitized and converted to Geographic Information Systems format for assessment of river conditions which existed prior to dam construction. Based on this information, Technical Appendix B (Corps, 1999b) reports on expected resultant habitat conditions pertinent to resident fish at a representative summer flow (Table 9-5).

Table 9-5. Summary of Amount of Expected Habitat Types in a Restored Lower Snake River after Dam Removal at a Moderate Summer Flow (24,000 cfs at Lower Granite Dam Site)

Habitat Types		Habitat Surface Area	
Velocity	**Depth**	**Acres**	**Percent**
> 2.0 ft/s	all depths	11,879	90.3
0.5 to 2.0 ft/s	< 10 ft	900	6.8
	> 10 ft	150	1.1
< 0.5 ft/s	< 10 ft	224	1.7
	10 to 35 ft	10	0.1
	> 35 ft	0	0.0
< 0.1 ft/s	all depths, to 35 ft	52	0.4

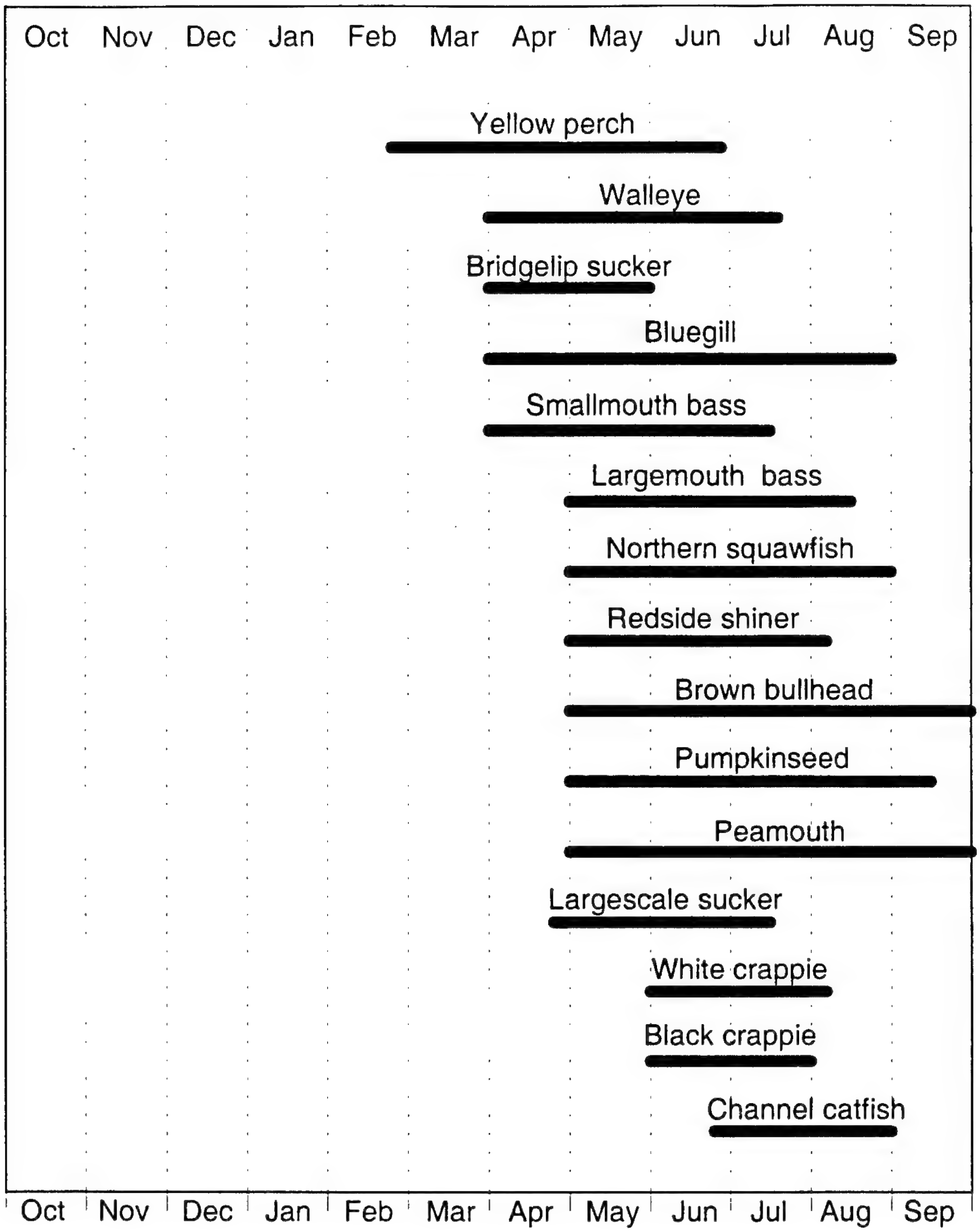

Figure 9-2. Approximate Spawning Times for Selected Resident Fish Species in the Lower Snake River Reservoirs

Source: Bennett et al., 1983

It is expected that under natural river drawdown with moderate summer flows surface area in the lower Snake River will be reduced to 38.8 percent of what currently exists (Technical Appendix B). The river gradient will be fairly consistent throughout the entire stretch with no steep rapids and only two which exceed a 3.0-m/km (10-ft/mile) drop and two which exceed a 0.9 m/km (5-ft/mile) drop. Long pools (greater than 1.6 km [1 mi]) will be relatively scarce, but will be interspersed throughout most of the river. A few deep pools (greater than 15 m [50 feet]) are predicted to form: two in the Ice Harbor Reservoir area and one just upstream from the confluence with the Palouse River (Lower Monumental Reservoir area).

Velocities will be relatively swift (greater than 1.5 m [5 feet/s]) in about 30 percent of the river and will exceed 0.6 m/s (2 feet/s) in about 90 percent of the river (Technical Appendix B). Shallow (less than 3.0 m [10 feet]) habitat with slow to moderate velocities will be greatly reduced to less than seven percent of the total habitat. Deep, slow, or standing water will be even less abundant (2.1 percent or less of the total habitat).

Breaching the dams will affect temperature regimes in the lower Snake River. It is likely that both the duration and the magnitude of water temperatures exceeding 20°C (68°F) will be less than with the dams in place (Yearsley, 1999).

9.2.2.2 Resident Fish Communities in Riverine Environments

Current resident fish communities, existing in related, free-flowing stretches of river, should give an indication as to what resident fish communities to expect in a free-flowing lower Snake River. Two sections of river that are closely related to the lower Snake River are the Hanford Reach on the Columbia River and the Hells Canyon Reach on the Snake River. The last remaining free-flowing stretch of the Columbia River above Bonneville Dam within the United States (river miles 343 to 393), known as the Hanford Reach, is located approximately 28 km (17 river miles) upstream of the confluence of the Snake River. Even more closely related to the lower Snake River is the free-flowing portion of the Snake River between Hells Canyon Dam and the upper influence of Lower Granite Reservoir (river miles 147 to 247), sometimes termed the Hells Canyon Reach.

Hanford Reach, Columbia River

The Hanford Reach contains a diverse fish fauna. Over 43 species of fish representing 13 families have been collected in this stretch of river since 1943. Redside shiner, northern pikeminnow, largescale sucker, bridglip sucker, peamouth, chiselmouth, and chinook made up close to 90 percent of samples collected by Gray and Dauble (1977) from 1973 through 1975. Abundance of resident sport fish, for example, smallmouth and largemouth bass, yellow perch, channel catfish, and crappies, appears to be low (Gray and Dauble, 1977). Although free-flowing, this stretch of river cannot be considered natural. Water levels are controlled by water releases from Priest Rapids Dam and can fluctuate 4 m (13 feet) (Dauble et al., 1989). However, species composition consists overwhelmingly of fauna native to the area.

Hells Canyon Reach, Snake River

Smallmouth bass, channel catfish, white sturgeon, northern pikeminnow, chiselmouth, redside shiner, and suckers were the major resident fish species found in the Hells Canyon Reach of the Snake River in the late 1960s (Keating, 1970). This is likely still the case (Nelle, personal communication).

Smallmouth bass population abundance, growth, and predation on salmonids in the Hells Canyon Reach of the lower Snake River were estimated in 1996 and 1997 (Nelle, 1999). When comparisons are done using number of fish per mile of shoreline, very little difference is seen in the abundance of smallmouth bass in the reservoir compared with that in the Hells Canyon Reach. Nelle (1999) estimated 397 smallmouth bass/km (639 smallmouth bass/mi) 175 mm (6.9 inches) and longer resided in this free-flowing stretch of the river. His estimate is almost identical to estimates made in Lower Granite Reservoir by Anglea (1997) and Naughton (1998). Anglea (1997) collected smallmouth bass in Lower Granite Reservoir during 1994 and 1995. He estimated 395 smallmouth bass/km (636 smallmouth bass/mi) 168 mm (6.6 inches) and longer. Naughton (1998), in 1996 and 1997, estimated 406 smallmouth bass/km (653 smallmouth bass/mi) 168 mm (6.6 inches) and longer in Lower Granite Reservoir.

Growth rates for smallmouth bass during their first 3 years of life are also very similar between the reservoir habitat and those found in the Hells Canyon Reach. Keating (1970), Anglea (1997), and Nelle (1999) all used scale analysis to estimate annual length increments for smallmouth bass. Keating and Nelle collected fish from the Hells Canyon Reach; Anglea collected smallmouth bass from Lower Granite Reservoir. Mean length increment for the first year of growth ranged from 87 to 82 mm (3.9 to 0.04 in) in the free-flowing river; Anglea (1997) found 81 mm (0.04 in) in the reservoir.

Although growth rates slow as the fish age in both habitats, the decline is more pronounced in the Hells Canyon Reach than in Lower Granite Reservoir. By the time smallmouth bass are 6 years and older, growth rates in the reservoir are considerably higher than those found in the Hells Canyon Reach.

9.2.2.3 Native Species

Species native to the lower Snake River evolved to live in a free-flowing river subject to spring flooding and associated increased turbidities. Most native species are broadcast spawners and prefer flowing water. Habitat changes resulting from a natural river drawdown, for example, higher water velocities, would benefit most native species. Species such as rainbow trout, bull trout, and mountain whitefish, which prefer cold water, would continue to use the area for corridors and over-wintering habitat. Prolonged cooler temperatures could lead to better connectivity to sub-populations of cold water species, particularly bull trout. Species that prefer flowing water, such as redside shiners, chiselmouth, peamouth, and bridgelip sucker, would likely benefit from a natural river drawdown and increase in abundance. The largescale sucker is a habitat generalist and is abundant throughout all reservoirs. Their numbers would likely decrease with the reduction in habitat associated with the natural river drawdown. They would, however, continue to be abundant throughout the lower Snake River.

Returning the lower Snake River to a riverine environment would improve habitat conditions for native species. Resulting habitat variables such as dissolved oxygen, pH, and water temperature would not perfectly reflect historic conditions because of the many other habitat changes within the basin; however, they would certainly be appropriate for resident species native to the area.

Habitat variables such as pool to riffle ratio, pool quantity and quality, and sediment particle size and distribution would be developed naturally as the river recedes and as annual spring flooding occurs over the first few years following dam removal. To a large degree, these variables would be dictated by forces beyond the control of this facility (for example, surrounding and upriver terrain, precipitation, and weather patterns). Again, if natural processes were allowed to occur, the resultant conditions would be adequate for native resident species.

White Sturgeon

Breaching the four lower Snake River dams would have a positive impact on white sturgeon. Dam passage would no longer be a barrier, allowing access to historical spawning and rearing habitat. Sub-populations would no longer be isolated within reservoirs. Suitable habitat would be enhanced and reestablished in the lower Snake River. Range of the white sturgeon population within the effected area would increase to include instream migrations from Hells Canyon Dam to the mouth of the Snake River and into McNary Reservoir.

9.2.2.4 Non-native Species

By far, the greatest effects to non-native resident fish would be the loss of shallow, backwater, and embayment areas. It is anticipated there will be a severe reduction in habitats with moderate to slow water velocities (less than or equal to 0.6 m/s [2.0 feet/s]; Technical Appendix B). These areas generally provide slightly warmer habitat, finer substrate, and submergent and emergent vegetation. Many non-native species require these conditions for spawning and rearing habitat.

The abundance of several species would decrease with drawdown. Carp, although a highly prolific species, would decrease in numbers because of a decrease in shallow water with a soft substrate. Largemouth bass and yellow perch, particularly dependent on vegetated areas, would all but disappear. Species such as black and white crappies, bluegill, pumpkinseed, and bullheads, which reside in backwater and embayment areas, would also decrease in abundance.

Channel catfish and smallmouth bass, however, are non-native species which typically do well in riverine environments. It is likely returning the lower Snake River to a near natural condition by breaching the four lower Snake River dams will lead to a slight increase in smallmouth bass abundance. However, growth of the older individuals will likely be slower than what now occurs in the reservoirs. Projected changes in water temperatures (longer duration of cooler temperatures, beginning earlier in the fall) are likely to slow smallmouth bass growth. Channel catfish abundance is not expected to be noticeably effected.

9.2.3 Predation on Juvenile Salmonids

Predation on juvenile salmonids would likely decrease under this alternative. Natural river drawdown would lead to increased flow velocity and decreased duration of elevated water temperatures in the lower Snake River. These combined effects would decrease smallmouth bass and channel catfish predation rates on salmonids. Predation by these species is currently limited by low water temperatures during spring months. Prolonging the duration of cooler water temperatures would provide smolts a longer 'safe passage' period. Cooler water temperatures would also reduce growth and consumption rates of the predators. Smaller fish would be less predacious on smolts. Salmonid predation would also decrease because increased velocities would shorten travel time through the lower Snake River reservoirs, thereby decreasing encounters with predators.

Predation by northern pikeminnow would also decrease. As with smallmouth bass and channel catfish, decreased travel time through the lower Snake River would decrease predator-prey encounters, directly decreasing predation rate. Cooler water temperatures would decrease metabolic rate, also leading to decreased predation. The most important effect on northern pikeminnow predation, however, would be the reduction in artificial structures associated with the dams which currently give northern pikeminnow the advantage. Although none of the current structures would be removed with natural river drawdown, flows would no longer be directed through the power house, over the spillway, or through the bypass.

The trauma of passing such structure would no longer be incurred by outmigrating juvenile salmonids, and overall predation would be reduced.

Changes in turbidity could also affect predation rates on juvenile salmonids. Particularly smallmouth bass, but also northern pikeminnow, are sight feeders. Increased turbidity during spring runoff stimulates salmonid outmigration and, at the same time, decreases predation efficiency for both smallmouth bass and northern pikeminnow.

An alternative hypothesis, however, suggests natural river drawdown would actually lead to increased predation. Decreased water volume, could lead to increased juvenile salmonid encounters with predators and increased predation rates. This hypothesis assumes predators and prey would redistribute evenly throughout the reduced volume of water, an unlikely assumption given habitat preferences and environmental patchiness (Petersen and Poe, 1998). Predators and salmonids tend to travel along shorelines.

Estimates of long-term responses of predator populations (smallmouth bass and northern pikeminnow) and estimates of predation on juvenile salmonids to natural river drawdown were developed by Petersen et al. (1999). Their modeling efforts were based on data collected in reservoirs of the lower Snake River and the two nearby free-flowing sections of river: the Hanford Reach of the Columbia River and the Hells Canyon Reach of the Snake River. Using bioenergetics modeling, they predicted the total mass of salmonids consumed by fish predators would be reduced anywhere from 67 to 82 percent compared to current conditions. The effects to spring migrants would be minor because of the minimal impact predation has during that time. However, predation on summer migrants (fall chinook salmon and presumably sockeye salmon) would decrease considerably.

Petersen et al. (1999) predict the population of northern pikeminnow would almost double in size with breaching the four lower Snake River dams. It is likely that both spawning and rearing areas for northern pikeminnow would be enhanced. They found northern pikeminnow currently living in the free-flowing Hells Canyon Reach were more robust and had higher growth rates than those sampled in the lower Snake River reservoirs.

The smallmouth bass population, on the other hand, was predicted to decrease in numbers. Currently both the reservoir and the Hells Canyon Reach populations have slow growth rates and very few large individuals. Petersen et al. (1999) predict numbers of smallmouth bass in the lower Snake River to be about half the current numbers if the dams are breached. They believe the smallmouth bass populations throughout the Snake River are currently limited by habitat constraints, particularly thermal regimes.

Estimated decreases in salmonid predation come from a combination of factors: changes in diet, smallmouth population size and structure, and temperature regime. Most important of these factors are the predicted changes in the smallmouth bass population and changes to their diet resulting from dam breaching. Changes in temperature account for 7 to 9 percent of the total decrease in predation. Crayfish and non-salmonid fish prey will continue to be important contributors to the diet of both smallmouth bass and northern pikeminnow.

9.3 Invertebrates (with Natural River Drawdown Alternative)

9.3.1 Short-term Effects

Effects to the invertebrate communities during and immediately following drawdown to the natural river level would be severe. Individuals unable to follow the receding water levels would be lost. Oligochaetes and other invertebrates which tend to burrow into the substrate to survive desiccation, would be lost. Although these organisms can survive long periods of drought, this strategy would not work in this instance where the substrates would not be resubmerged in water.

During the 1992 test drawdown of Lower Granite and Little Goose reservoirs, Cushing (1993) found some crayfish and molluscs were able to successfully follow the receding water level, particularly those along steep slopes. Dauble and Geist (1992) observed 'clam tracks' up to 3 m (10 feet) long. However, crayfish and molluscs were the most noticeably impacted organisms other than fish (Dauble and Geist, 1992). Schuck (1992) estimated tens of thousands of crayfish died during the test. The ESA species of concern *A. californiensis*, as well as *A. nutalliana*, were found dead and dying in exposed areas (Cushing, 1993).

9.3.2 Long-term Effects

Although the initial losses would be extreme, the invertebrate community would begin recovering almost immediately. Structure would shift from a reservoir community dominated by worms and midges to a more riverine community, similar to that present in the upstream free-flowing sections of the Snake River. Drift from the Snake River above the impounded area would provide a rich source of colonizers to take advantage of the newly created riverine conditions (Brusven et al., 1974). The Clearwater, Tucannon, and Palouse rivers, and other tributaries, would also provide some colonizers to the lower Snake River. As the habitat changes, overall numbers and biomass of worms would decrease, being replaced by caddis flies (Trichoptera), mayflies (Ephemeroptera), stoneflies (Plecoptera), and others which prefer higher velocities and dissolved oxygen and are abundant in the free-flowing waters upstream of reservoirs.

Mollusc diversity would also increase. Cooler, well-oxygenated water would provide more suitable habitat for molluscs currently persisting in the Hells Canyon Reach but no longer present in the lower Snake River. These species should be able to expand their range into habitat recreated by dam removal in the lower Snake River.

Crayfish abundance will recover quickly. The high reproductive potential of the signal crayfish will enable it to rapidly repopulate newly exposed cobble and gravel habitats. Based on habitat changes, density of crayfish, in the long term, is likely to be similar or better than current conditions.

9.4 Terrestrial Resources (with Natural River Drawdown Alternative)

Implementing the natural river drawdown would cause average water levels to drop from between 29 m (94 feet) below MOP at Ice Harbor Reservoir to 34 m (110 feet) below MOP at Lower Granite Reservoir. This drop would occur over several weeks with an average drop of about 0.6 m (2 feet) per day. It would affect habitats within the study area in various ways. Furthermore, for some HMUs, especially those currently accessible only by boat, the drawdown may make them inaccessible to the public, if the only practical access route is through private land.

9.4.1 Riparian Habitat

The most severe adverse impact from the drawdown would likely be to current riparian areas, which are created and maintained by the adjacent water source. The drawdown would remove most of that water source and cause the majority of current riparian vegetation to desiccate, eventually die, and be replaced by upland vegetation. A small amount of riparian vegetation, if well established, would be able to survive without the adjacent water source, for example, Russian olive can survive with 203 mm (8 inches) of precipitation and would be expected to persist if already established (WSU Coop. Ext., 1983). However, most of the existing riparian vegetation would no longer be considered riparian since the water's edge would be several hundred feet to several hundred yards from the vegetation with the drawdown. Additional riparian vegetation that may survive the drawdown would include that present along tributary streams, at seeps and springs, and on the irrigated HMUs, (or that at least receives water from runoff or subsurface flow from that irrigation). However, the latter would be contingent on the Corps' continued irrigation of the HMUs. Irrigating these areas after a drawdown would be expensive since either irrigation intakes would have to be extended long distances to access Snake River water or deep wells would have to be drilled at each HMU. Without irrigation for HMUs, much of the vegetation would desiccate and die. This would result in heavy fuel-loading with susceptibility to fires because of the proximity of railroads to most of the HMUs (USFWS, 1994).

Natural river drawdown would cause the loss of many existing embayments, backwaters, other still water areas, and fringe areas along the reservoir and island shorelines, which are the locations for most of the current wetlands. Some wetlands would become established along the new shoreline, although they would likely be narrow fringes. There may be some wetland development in the exposed floodplain depending on factors, such as frequency and duration of flooding in the floodplain and distribution, composition, and fate of existing sediments following drawdown. If the remaining sediments are too high to be regularly flooded, then wetlands would likely not develop. Likewise, if the floodplain substrate is composed of porous sediments, water would likely not be retained long enough following flooding for wetland development to occur. However, we believe it is reasonable to assume that wetland acreage along the lower Snake River following the drawdown would end up being somewhere between the 4 ha (10 acres) present before the facilities and the approximately 143 ha (353 acres) present in 1997.

Hanrahan et al. (1998) projected in their draft report that most sediments would be removed from the Lower Granite Reservoir within 5 years. It is likely that sediments would be moved and deposited downstream of Ice Harbor Dam once they enter the still waters of McNary Reservoir. The Corps (Technical Appendix F) projected that about 16 km (10 linear miles) of the nearshore areas along the left bank of the Columbia River downstream of the mouth of the Snake River would receive sediments (Corps, 1999). They project a few feet of sediments would be deposited within a couple of years of the breaching of all of the dams. Additional sedimentation would occur further downstream to McNary Dam along both shorelines of the Columbia River in certain areas. Depending on the final configuration of the deposition, it is likely to result in large increases in wetlands, potentially on the order of several hundred acres. In addition, it could result in a smaller amount of wetlands being at least partially filled.

Existing stands of purple loosestrife should be set back significantly through desiccation when their preferred wetland habitats dry up after the drawdown. However, because the bare exposed mudflats following the drawdown would be conducive for seed germination (Coombs, 1996) and the return to a low gradient riverine environment can offer many opportunities for loosestrife colonization (Thompson, 1989), it is difficult to predict how purple loosestrife would respond following the drawdown. A weed

control plan that addresses rapid response to any purple loosestrife establishment following drawdown would help ensure control (Coombs, 1996; Thompson, 1989).

Following a natural river drawdown, a drawdown zone consisting of bare substrate (mainly silt and sand) would be exposed, totaling over 8094 ha (20,000 acres). Depending on timing of the drawdown, herbaceous plant growth would begin within a matter of days to several months. As shown by Phillips (1993), the diversity of plant species pioneering on exposed soils following the March 1992 drawdown showed an increase, even into July. However, many of these plants would likely die as moisture in the soil would continue to decline with a permanent drawdown. As mentioned earlier, nearly all of the 3,000 individual wetland plant species planted from the OHWL down to MOP during the March 1992 drawdown, were dead by July 31 (Phillips, 1992). Causes for most mortality were possibly reduced nutrients and water-holding capacity in the soil and perhaps other variables working to prevent long-term survival of those wetland plants tested. River fluctuations, precipitation, groundwater, and possibly irrigation would have to provide all the moisture for reestablishment of vegetation following the drawdown

Wave action and subsequent bank sloughing or slipping are currently substantial along the reservoir shorelines, partially from soil characteristics (Asherin and Claar, 1976) and partially from reservoir operations. Many of these same soils would be present along the Snake River's new shoreline; however, the disturbance from operations would be removed. The bare shoreline of the new Snake River channel should eventually be stabilized with riprap, rock outcrops, and other stable substrates, as well as vegetation in a relatively short time. The Corps plans to place riprap along over 82 km (51 miles) of shoreline along the Snake River to help stabilize railroad and road embankments and shoreline areas near the dams.

9.4.2 Upland Habitats

Dam breaching activities would result in some short-term impacts to upland habitats through areas needed for stockpiling materials and haul roads. The Corps (Technical Appendix L) estimates that 870.1 hectares (2,150 acres) of existing habitat would be adversely impacted with breaching activities (Corps, 1999). They estimate that only about 28.3 hectares (70 acres) of this would remain unvegetated in the long term.

Aside from the above, any changes to current upland habitat types attributable to the natural river drawdown should be relatively minor in the long term, providing that current management activities remain unchanged. However, if irrigation on HMUs is discontinued due to high costs, food plots and other agricultural lands managed for wildlife could be eliminated, or at least significantly reduced in acreage and quality. If management emphasis of facility lands change, shrub-steppe and grassland habitats may be affected. For example, if the facility lands become managed by private interests for grazing, the quality of the shrub-steppe and grassland for wildlife habitat would likely decrease. Aside from the riparian zone, much of the area exposed with a natural river drawdown would eventually become some upland habitat type. It would be preferable for wildlife, and from an ecosystem perspective, for this upland habitat to be represented by native plant communities, such as grassland and shrub-steppe. This would likely require human intervention, as discussed in later sections. Management activities such as eliminating grazing and weed control should help these habitats to continue to improve in quality.

9.4.3 Natural Colonization

Colonization of the exposed floodplain and shoreline following a natural river drawdown, would occur through wind- and water-dispersed seed from many plant species in and along the Snake River and from the sediment seed bank. Robberecht (1998) analyzed sediment cores for seeds at twelve sites within the study area and found that nearly one-half (47 percent) of the seeds were viable. About 85 percent of the seeds were from forbs, 5 percent from trees, 2 percent from shrubs, 1 percent from grasses, and 7 percent unknown. The greatest number of seeds occurred near the upland/water interface, declined rapidly to 0.5 m (1.6 feet) water depth, and was the lowest at 5 m (16.4 feet), the deepest sample sites. Analysis of the sediment cores showed a sufficient seed bank down to 5 m (16.4 feet) in water depth to allow rapid colonization of exposed sediments (Robberecht, 1998). Unfortunately, the current water depth over most of the sediments that would be exposed with the drawdown is much deeper than 5 m (16.4 feet). As a result, we do not know what those sediments contain, although some of the seeds found in the sediment samples are from wetland plants or at least plants that need significant amounts of moisture to become established and survive. Adequate moisture for their survival would not be available in most areas along the newly exposed shorelines, except areas relatively near the new river channel. Therefore, those plants that successfully colonize the majority of the exposed sediments would most likely be those that can tolerate low moisture conditions. Malanson (1993) stated that seedbanks may be more important vital attributes for still wetlands than for riparian sites subject to flowing water. Historically, the plants present in most of these areas were grassland and shrub-steppe species. While some of those species were found in the sediment seed bank or have wind-borne seeds, they would be competing with several weedy, aggressive, and sometimes noxious plant species. As mentioned earlier, 54 percent of the seeds in the substrate below the OHWL and 62 percent of the plant species on the exposed substrate during the test drawdown were exotic species.

However, as stated earlier, weed infestations on adjacent private lands can be extreme, indicating an ample source of wind-borne seed from such exotics as knapweeds and yellow starthistle are present in the area. Many of these weedy and sometimes noxious non-native plants can become established in low moisture areas within the study areas and may become quickly established on exposed sediments following a drawdown. Where moisture is adequate for a larger variety of native species, they would still undergo competition from robust growth of weedy species (for example, cheatgrass, reed canarygrass, and false indigo).

Conditions would be more conducive for high quality riparian development following drawdown than that which occurred naturally along the reservoirs, because the soils would be deeper and more productive than the rocky, shallow soils along most of the reservoir shorelines. Also, shoreline slopes should be flatter than the current steep slopes, at least once the Snake River begins to stabilize. Furthermore, the amount of riprap would be reduced from 156 km (97 miles) of shoreline to 82 km (51 mi) (nearly 50 percent). The Corps (1995) projected that a riparian zone should become established fairly quickly following a natural river drawdown, although it would consist mainly of herbaceous and shrubby vegetation initially. Vegetation reestablishment would be guided by the river's hydrograph (water levels over time), weather, and other ecological factors. To ensure that the drawdown does not allow the colonization of 8,094 ha (20,000 acres) or more of exotic weeds, but instead results in the establishment of native plant communities, coordinated management actions would also be needed (such as revegetation efforts and weed control). Additional specific management actions needed to optimize floodplain and riparian restoration will be developed with a mitigation team that will be formed if the Natural River Drawdown Alternative becomes the Corps' selected alternative.

9.4.4 Wildlife Resources

As stated above, there would be significant losses in habitat with the Natural River Drawdown Alternative, primarily in the short term. Furthermore, most of the existing riparian vegetation that survives the drawdown would no longer be considered riparian with the loss of the adjacent water's edge, and it would lose much of its value for wildlife. Reductions in many wildlife species would occur through direct mortality and through habitat loss or conversion, at least in the short term, until a riparian corridor and functioning floodplain have been reestablished, and upland areas have recovered following stockpile and road removal. Conversely, the drawdown would have an immediate positive effect on some species such as killdeer and other shorebirds, as there would be thousands of acres of exposed mudflat habitat available, at least temporarily, until vegetated. Additionally, if the Corps continues to irrigate HMUs and attempts to create corridors between them and the new shoreline, adverse impacts from the drawdown should be reduced for many wildlife species. Many impacts would be reversed, or at least reduced, following the restoration of a properly functioning riparian zone.

9.4.4.1 Game Birds

All of the game birds may experience increased mortality from predation while crossing the drawdown zone to get water. Gamebird chicks and other animals may experience difficulty crossing the steep ravines that would cut through silt deposits in side canyons and other tributaries. Furthermore, the difficulty some young birds currently may have crossing the extensive riprap along the reservoir shoreline, would be exacerbated by the increased distance from habitats across the drawdown zone and steep cuts in the silt deposits down to the new shoreline. Without irrigation, most cereal grain and food plot plantings would have to be terminated, which would mostly affect upland game birds, mule deer, and some non-game birds. Ring-necked pheasants and California quail use the various riparian habitats and HMUs year-round for roosting, feeding, escape, and sometimes nesting cover. The short-term loss of much of this habitat would result in significant adverse impacts from the drawdown. The severity of the impacts would depend on the restoration scenario implemented. For example, continuing to irrigate existing HMUs and developing vegetated corridors down to the new shoreline would lessen impacts to these game species.

In the short term, about 809 ha (2,000 acres) of upland habitat would be vegetatively impacted by drawdown activities. This would result in direct effects to species using upland habitats for nesting or cover and indirect effects to others. These effects should mostly disappear within a few years, depending on the habitats affected.

If the drawdown occurs, there would be a change in invertebrate populations and community structure because of much less aquatic invertebrate habitat, as well as different aquatic habitat (riverine as opposed to lacustrine) and changes in the surrounding terrestrial habitats (for example, temporary loss of some riparian habitat and possibly HMUs, isolation of much of the existing habitat from a permanent water source, restoration of a properly functioning riparian system in the long-term, etc.). Significant changes in insect communities could affect young game birds, waterfowl, many neotropical migratory birds, bats, and other wildlife species that depend on insects.

9.4.4.2 Waterfowl

Waterfowl species generally benefit from stable water conditions and the establishment of riparian and wetland vegetation. As stated earlier, several waterfowl species currently using the study area were not documented until the reservoirs were in place. Therefore, changing the reservoir environment to

riverine, and reducing existing wetland areas significantly would be expected to have adverse impacts to some waterfowl species and change the current species composition.

Waterfowl production may be adversely affected because of loss of existing wetland and shallow-water habitats with the drawdown. Also, current man-made goose nesting structures at the HMUs would likely be abandoned. However, cliff-nesting by Canada geese would be relatively unaffected by the drawdown, except that in most cases, broods would have a longer initial trip to the water's edge, while the initial flush of sprouting herbaceous growth adjacent to the water's edge following drawdown could be beneficial. Some woody vegetation would likely become established, which would hinder access by goslings and improve conditions for predators. Land bridging would occur with some islands currently used by Canada geese. USFWS (1993a,b) suggested that two islands with a long history of goose production failed to produce during the Lower Granite drawdown, suggesting losses due to predation. Asherin and Claar (1976) also found a significant loss of nests and some adult waterfowl from land predators with land bridging that occurred in 1975 on McNary Reservoir. Complete bridging is not necessary for access by predators as some predators (for example, coyote) can swim to islands depending on flows and width of channel.

Some waterfowl brooding areas, such as grassy sites and other perennial forb and grass (AFG) habitats are maintained by subirrigation from the reservoirs (USFWS, 1992) and would be lost with the drawdown. Also, with a significant drop in water level, such as with the natural river drawdown, access to brooding areas would be very difficult for waterfowl broods because of large expanses of mudflats, heavy weedy growth, and riprap barriers. Predation would likely be significant, at least until brooding areas are developed near the new shoreline.

As a benefit, the drawdown would expose several islands and sandbars formerly important for Canada goose nesting. Additional sand and gravel bars may form in the future with a more natural river flow regime.

With the natural river drawdown, submerged aquatic plants would be significantly reduced because of the increased water velocities (McKern, 1976). Loss of many aquatic plants and changes in benthic communities could create food shortages for some of the thousands of waterfowl during critical migration and wintering periods. This would have the greatest effect on diving ducks, widgeon, and coots which feed primarily on aquatic plants such as pondweeds (*Potamogeton* spp.) and waterweeds (*Elodea* spp.) (USFWS, 1993a). Aquatic plants can also be a locally important food source for Canada goose broods (Tabor et al., 1981).

The highest average monthly count of mallards during migration and winter on a 4.8 km (3-mile) stretch of the Snake River from the town of Clarkston downstream was 3,883 birds, based on studies conducted from 1955 to 1965 (Buss and Wing, 1966). From 21 aerial waterfowl surveys conducted since 1978, the highest count of mallards for the same stretch was 2,800 in 1995. This suggests that at least some of the waterfowl that use the reservoirs now would continue to use the Snake River with the drawdown. However, the drawdown would eliminate most emergent wetlands, backwaters, and slack water of the reservoir, which would decrease the attractiveness of the area for many species. Therefore, some waterfowl would probably begin wintering and stopping during migration on other nearby reservoirs (McNary Reservoir for those species using the lower reaches and the three Hell's Canyon reservoirs for those using the upper reaches) or elsewhere in the flyway, depending on available food resources. McNary Reservoir, from the Snake River mouth to Ice Harbor Dam, is a waterfowl reserve with waterfowl hunting not allowed, which should further increase its attractiveness to some waterfowl.

9.4.4.3 Shorebirds

Mudflats would dramatically increase for a short time following drawdown allowing invertebrates to be exploited by shorebirds. This should lead to some increase in shorebird use of the study area during the migration seasons following drawdown until mudflats become established with weedy growth and other vegetation. However, if the Snake River is not on their normal migration route, many shorebirds would not even be aware of this potential resource. Shorebird habitat should again become limited as it was prefacility. Nesting habitat for killdeer and spotted sandpiper, bare gravel and sand bars, should be plentiful in and along the river once it stabilizes and has a more natural river flow regime.

9.4.4.4 Colonial-nesting Birds

Some of the existing islands would increase in size (as the reservoirs drop) without becoming land-bridged, and other islands would become exposed. If the additional island habitat is suitable, colonial nesters such as terns and gulls could benefit. However, with the drawdown, there may be an increase in invasive exotic plants (such as Russian olive and false indigo) on the islands. These and other exotic weeds, along with some native plants as well, may cover the area needed by groundnesters and also provide perch sites for aggressive nest predators such as crows, ravens, and magpies. Furthermore, the loss of reservoir habitat would reduce the amount of foraging habitat for some of these colonial nesters anyway.

Reduction of embayments, backwaters, wetlands, and other still waters, along with resident fish numbers following drawdown, would adversely affect herons, terns, and gulls. While there would still be a forage base and some habitat available to support some of these species, it would definitely be reduced. There would be a short-term increase in food availability for these piscivorous birds resulting from stranding of fish during the drawdown. Reduction in the populations and distribution of colonial nesting birds is not necessarily an unwanted outcome for two reasons: 1) flowing river systems do not normally have large numbers of colonial-nesting birds associated with them, and 2) many of these birds are predators of salmon smolts. Removing facilities where these birds often congregate to feed on smolts and causing a reduction in the birds numbers should help improve conditions for salmon survival, the objective of the measures in this feasibility study.

9.4.4.5 Raptors

Small mammal populations would be severely reduced from the loss of riparian habitat, which would also adversely impact many of the raptors within the study area, as many rely on them for prey. Aside from prey availability, raptors are associated with riparian habitat for nesting and perching. The eventual loss of most riparian habitat, and the long distance remaining between trees and snags and the new shoreline, would also adversely impact many raptors. Although they can use cliffs and rock outcrops for perches as well, most of these would be far from the shoreline and eventual riparian zone. Although a riparian zone may develop relatively quickly and become populated with small mammals, trees for perching and nesting would take many years to develop.

Osprey are currently nesting along the reservoirs in small numbers. They would likely continue if nest sites are not too far removed from the new shoreline. Bald eagle wintering numbers could increase once fall chinook spawning is re-established and spawned out carcasses become available in abundance.

9.4.4.6 Other Non-game Birds

Because of the reliance on riparian habitats by many bird species, and the eventual loss of most riparian vegetation following drawdown, there would be at least short-term negative impacts to many bird

species. Restoring a properly functioning riparian corridor along the new Snake River channel should eventually allow many of the current and former bird species to return.

The importance of HMUs in helping provide riparian habitat is illustrated by the fact that 10 breeding species that depend on riparian habitat were found there but not at the non-irrigated sites (Rocklage and Ratti, 1998). In addition, during the fall and spring, 20 and 13 species, respectively, that depend on riparian habitat were found at the HMUs but not the non-irrigated sites. Although the Rocklage and Ratti study was more extensive and resulted in more species being documented, twelve species found prefacility by Dumas (1950) were not found in the recent study. Nearly all of these species would be found in riparian forest habitat. This helps indicate how the impoundments affected some bird species found along the lower Snake River and points out that the HMUs, at least to date, apparently do not have the necessary habitat components to attract these former breeding species. Restoring a riparian corridor along the new Snake River channel should eventually allow most of those former species to return.

Some riparian trees within the study area are just becoming large enough to be used by some cavity-nesting birds, such as downy woodpecker and black-capped chickadee, although these species are still rarely present. Also, some are now large enough to provide perches and roosts for bald eagles and other raptors. Furthermore, their continued development may make them attractive to certain species for nesting such as great blue heron. However, with the natural river drawdown, there would be a loss of most of the existing larger trees and there would be a significant time period (20 to 50 years) before larger trees would again be present in the new riparian corridor. Thus, the drawdown would set back the use of riparian habitat by some species by several decades.

With the drawdown, the HMUs would become more isolated because riparian habitat now present along the shoreline, and which helps connect them somewhat to each other, would desiccate and die. This would reduce the effectiveness of the HMUs for providing a travel and dispersal corridor for many bird species, as well as deer, small mammals, furbearers, amphibians, and others. The corridor benefits provided by riparian habitat would be severely compromised if irrigation is not continued on HMUs until a riparian zone has been established along the new shoreline.

Since there would be a permanent reduction in emergent wetlands within the study area following a natural river drawdown, species which depend on this habitat, such as marsh wren, yellow-headed blackbird, would be significantly impacted. There would likely be a drastic reduction in successful nesting by these species, even while vegetation remains alive, except where tributaries or springs maintain emergent vegetation near open water.

9.4.4.7 Big Game Animals

Reduction in riparian habitat would adversely impact deer use of the study area in the short term. There would be a reduced attractiveness to deer following a drawdown since there would be a large drawdown zone without a corridor leading from adequate habitat down to the river. Impacts to these important deer habitats could reduce the area's deer populations, with some estimates including severe negative effects (Corps et al., 1995). However, the restoration of a properly functioning riparian zone along the river in the future would positively affect deer populations. Also, drawdown could expose islands that once revegetated could be used for fawning (Asherin and Claar, 1976).

If HMUs are retained and corridors developed between some of them and from them down to the river, adverse impacts would be lessened. Eventually, with a successful restoration program, habitat should reach a quality similar to or better than that which existed along the river before inundation.

9.4.4.8 Small Mammals

The drawdown would likely have a short-term adverse impact on these species as riparian habitats would decrease initially. Continuing to irrigate HMUs and providing a corridor from HMUs down to the river would reduce some impacts. HMUs had twice as many small mammal captures (125) as either non-irrigated woody sites (63 captures) or woody drainages (62). Maintaining HMUs with irrigation following drawdown would help retain populations of small mammals that could potentially disperse to riparian habitat along the Snake River once it becomes established. Hanson et al. (1990) found that fragmented riparian habitat decreases diversity and changes species composition, especially regarding mammals. In the long term, with adequate riparian restoration, small mammal populations and community structure would likely return to something similar to prefacility conditions. Those small mammals preferring upland habitats, such as Ord's kangaroo rat and bushy-tailed woodrat, may benefit from the increased upland habitat following the drawdown.

9.4.4.9 Bats

Those bats which rely on riparian habitat for roosting and foraging would be adversely impacted with the drawdown, at least in the short term. However, riparian restoration following drawdown should benefit most species through increased riparian habitat and a more continuous habitat corridor along the river. Since bats in the study area rely exclusively on insects for food, changes in invertebrate populations following a drawdown may also affect bat populations and diversity.

9.4.4.10 Furbearers

There would be a short-term increase in forage base for many terrestrial furbearers, due to the stranding of fish, crayfish, and mussels, immediately following the drawdown. However, there would also be a loss of important riparian habitat which would adversely impact most furbearers. The impact to these species would be lessened if the Corps continues to irrigate the HMUs and if habitat corridors are developed between HMUs and the river.

The loss of riparian habitat would adversely impact aquatic furbearers (USFWS, 1992). In the long term, adequate riparian restoration following drawdown should allow recovery of mink, otter, and beaver. Muskrats are more dependent on emergent wetlands, and they would be significantly impacted since wetlands are projected to be eliminated with the drawdown. However, some wetlands would develop in the new floodplain and several hundred wetlands acres may develop along the McNary Reservoir shoreline. The total impact on aquatic furbearers is dependent on the disposition of HMUs, the configuration of the river once it has stabilized (for example, many side channels and backwaters could increase wetland area), and the riparian/floodplain restoration plan.

With the drawdown, beavers would have no food source associated with water in the short term, except at the few tributaries. Further, they would be exposed to predation as they attempt to reach food sources (USFWS, 1993b). One benefit of the temporary reduction in beaver populations is that it may decrease the establishment time for woody riparian species.

With the drawdown, there would be an immediate reduction in denning opportunities for otters, since existing riprap, beaver dens, and other den sites would be hundreds of feet from the water's edge. At least some riprap would be immediately placed along the shoreline near the breached dams and other areas needing shoreline protection. When completed, linear riprap coverage would be reduced from the current coverage of about 156 km (97 miles) of shoreline to about 82 km (51 miles). Once the river stabilizes, and assuming substrate is suitable for muskrat and beaver dens, otter denning opportunities

should eventually return. In addition, molluscs and crayfish populations, important prey species for otters, would be drastically reduced with the drawdown (USFWS, 1993a).

9.4.4.11 Amphibians And Reptiles

Painted turtles and most amphibians in the study area prefer or require riparian areas, emergent wetlands, backwaters, embayments, or other quiet or slow-moving water. Since the drawdown would eliminate or drastically reduce that habitat, at least in the short term, there would be adverse impacts to those species. Asherin and Claar (1976) did not believe changes in riparian habitat would have much effect on the abundant racer since it uses a variety of habitats. Although gopher snakes are also found in various habitats, they would be more affected since they rely more heavily on small mammals which would be adversely affected by the drawdown, at least in the short-term. Rattlesnakes often congregate near riparian areas and would at least be locally impacted by the short term loss of riparian habitat.

One reason suggested for fewer amphibians and reptiles than expected in riparian areas in the study area was that the riparian habitat was newly developed (Loper and Lohman, 1998). This has resulted in a lack of maturity of the vegetation community and less time for colonization by amphibians and reptiles. With the drawdown, the process of maturation of the riparian habitat and subsequent colonization would be set back several decades. There would be a lessening of impacts if HMUs continue to be irrigated, and habitat corridors are established down to the new shoreline.

Another potential problem identified with current amphibian and reptile numbers and distribution was that riparian habitats were isolated, with long stretches of riprap, bare shoreline, or very narrow habitat corridors between them (Loper and Lohman, 1998). With the development of a natural riparian corridor sometime in the future following drawdown, habitat corridors for dispersal should be much improved over the current conditions.

9.4.4.12 Threatened and Endangered Species

The analysis of potential impacts of the proposed alternatives to all threatened, endangered, and proposed species, would be made in the context of the Endangered Species Act of 1973, as amended. Under section 7 of the Act, the Corps would consult and confer with the USFWS and NMFS regarding those species, following selection of a preferred alternative.

9.5 Environmental Contaminants (with Natural River Drawdown Alternative)

Effects to aquatic and terrestrial organisms from the Natural River Drawdown Alternative are complex. The drawdown of the lower Snake River reservoirs poses potential toxicological threats to fish and wildlife and their habitat from Lewiston, Idaho, to the Pacific Ocean. At this time, the effects to fish and wildlife resources from the resuspension of impounded sediment into this dynamic system are difficult to determine. Point and nonpoint sources of environmental contaminants have been identified from upstream agricultural and industrial origins, and some would be found in sediments behind the dams. These contaminants are known, under certain conditions, to cause adverse effects to aquatic-related organisms. However, information on the contaminants in the sediments and their distribution is insufficient to fully evaluate whether or not adverse impacts to organisms could result from drawdown.

9.5.1 Redistribution of Sediments

Should the Natural River Drawdown Alternative be implemented, redistribution of sediments would occur, altering the morphology and potentially the water quality of the lower Snake River.

Approximately 50 percent of the 76.5 to 114.7 million cubic meters (100 to 150 million cubic yards) of sediment impounded behind the four dams is projected to erode and be transported downstream within the first few years following the breaching of the dams. Most of the fine sediments are anticipated to settle in the McNary Pool in the Columbia River. The very fine sediments that do not settle in the McNary Pool would continue to be transported downstream and ultimately settle in the Columbia River Estuary or the Pacific Ocean. If redistributed sediments contain certain levels of contaminants, they could pose a threat to fish and wildlife resources.

The resuspension and deposition of sediments resulting from the Natural River Drawdown Alternative may have varying effects on organisms. Potential threats to fish and wildlife from contaminated sediment and impaired water quality include increased availability of contaminants to organisms and potential exposure of additional contaminants during critical life stages. Increased exposure to contamination may affect organisms directly, bioaccumulate through the food chain, alter the prey base, or cause alterations of habitat. Adverse effects to fish and wildlife species from exposure to toxic levels of contaminants may include mortality, physiological responses, impaired reproduction, immune system alterations, behavioral changes, or avoidance or loss of important habitat. The timing of release of the impounded sediment is important. Untimely resuspension of sediments could have detrimental effects to some organisms. Exposure of organisms in the lower Snake River to newly available contaminated sediment could be relatively short (acute exposure) in some areas and longer term (chronic exposure) in other locations. Acute exposure would occur following the initial breaching of the dams causing resuspension of sediment. Long-term exposure (chronic exposure) of organisms to contaminated sediment would occur in the Snake and Columbia rivers where contaminated sediments would settle.

The removal of the four lower Snake River dams could make additional contaminated water and sediment available to organisms. When the earthen portions of the dams are removed during implementation of the Natural River Drawdown Alternative, sediment behind the dams would be resuspended. This would expose fish, wildlife, and their habitat to potentially toxic concentrations of resuspended contaminants. The eroded materials would most likely be redeposited in Lake Wallula (McNary Pool) between the Snake River and the Wallula Gap on the Columbia River. Depending on the timing and route of deposition of resuspended sediment, impacts from contaminated sediment to fish and wildlife would vary. Sediment resuspended in the water column would become available to organisms by direct uptake.

9.5.2 Resuspension

Resuspension of sediments from drawdown is of concern to the health of fish and wildlife resources. The fine sediments would be suspended in the water column for an unknown period of time before their anticipated settling in the McNary Pool and locations further downstream in the Columbia River. Resuspending large volumes of potentially contaminated sediment could expose organisms to concentrations of compounds that could have sub-lethal or lethal effects. Released water and sediment may affect fish and wildlife resources through direct exposure and bioaccumulation through the food chain. Wind and rain erosion and channel incision processes will also contribute to additional sediment resuspension. Potentially contaminated sediments entering the Columbia River would contribute to an already impacted system.

9.5.3 Deposition

Some of the material deposited within the lower Snake River may create shoals and/or sand bars. Fine materials accumulating in shallow areas, mud flats, or other depositional zones would become available to organisms living in or utilizing these areas for foraging. Waterfowl, wading birds, and other birds and

mammals would become exposed to potentially contaminated sediment by foraging in these habitats. Sediments settling in the McNary Pool may possibly remain there for a long period of time. Contaminated sediments redeposited in the McNary Pool could pose a threat to waterfowl and other migrating birds that utilize the McNary National Wildlife Refuge.

9.5.4 Exposure of Sediments

Following implementation of the drawdown, some sediments would be resuspended quickly. Other sediments would become resuspended more slowly through erosion from heavy rain, flood events, wave action along the newly created shoreline, and changes as the river meanders. Contaminated sediment that had been entrapped and unavailable to organisms would be mobilized. This may prolong the exposure time of organisms to potentially contaminated sediment.

9.5.5 Environmental Contaminants

Environmental contaminants have and continue to enter the lower Snake River from a variety of non-point and point sources. Sources include agricultural runoff, paper and pulp mills, storm water runoff, grazing, domestic wastes, and hazardous materials releases. Under current reservoir conditions, elements and compounds are bound to sediment and organic matter and are present in the pore water (water in between the sediment) and open water. The release of impounded water and sediment during the drawdown alternative will disrupt existing conditions in the reservoirs and the lower Snake River and the Columbia River. Changes in water quality parameters such as temperature, pH, hardness, alkalinity, and salinity can alter the toxicity and degradation rate of some of the compounds in the water and sediments currently in the system. Organic compounds can become biologically available when sediments are disturbed. However, the amount of desorption that occurs depends primarily on sediment composition and the persistence and concentration of the chemical (Thomas 1996). Once liberated into the environment, it is unknown what the interdependent and interrelated reactions of the sediment, organic matter, and water may be. When multiple contaminants are present in a system, effects can be additive, synergistic, or antagonistic. This means the combination of toxicants in the environment could produce a response that is simply additive or greater or less than that expected by addition of these individual responses. Impacts to fish and wildlife from contaminants in the lower Snake River and Columbia River systems will change as the physical and chemical properties of the water and sediment changes from the drawdown event.

It is difficult, with existing information, to determine what the potential toxicity to organisms may be considering the large quantities of sediment and water, variety of compounds, and anticipated reactions that would be created by the drawdown scenario. Many of the toxic compounds that have, are, and will enter the river have chemical properties that bind or adhere to sediment particles and persist in the environment for many years. Contaminants are most often associated with the fine sediment particles because of their high surface area to volume ratio. Some of the chemical properties of these compounds enable them to persist in the environment at high enough concentrations to cause injury to organisms. Availability of contaminants is greatly affected by physical characteristics of sediments such as particle size, distribution, total organic carbon and mineral composition (Seelye and Mac, 1984).

Organochlorine and organophosphate pesticides, petroleum hydrocarbons, dioxins and furans, heavy metals, and PCBs, have been detected in the lower Snake River system. Resuspension of these compounds resulting from the Natural River Drawdown Alternative would increase the bioavailability of these contaminants to organisms. Seelye et al. (1982) have shown that persistent compounds such as DDE and polychlorinated biphenyls (PCBs) can be accumulated by fish directly from exposure to resuspended sediments. Low concentrations of persistent compounds such as some organochlorine

pesticides, PCBs, dioxins, and furans can bioaccumulate within the food chain and impair reproduction in top level predators, such as the bald eagles. In addition, many of these organochlorine compounds disrupt the immune or endocrine system, and very low concentrations of these chemicals could impact fish and wildlife during sensitive life stages.

The U.S. Environmental Protection Agency (EPA) has classified the middle Snake River as having marginal water quality (PNL, 1995). Sampling and characterization of sediments in the lower Snake River has been limited. An EPA report (EPA, 1992) has identified pesticide problems in the Clearwater River which enters the lower Snake River system in the upper end of the Lower Granite Reservoir. Contaminants related to industrial sources along the lower Snake River have been detected during sediment sampling studies by the Corps (Anatek Labs, Inc., 1997) and Potlatch Corporation's Lewiston Complex (Potlatch, 1998). Sediment and water samples collected by the Corps during the 1997 Lower Snake River Sediment Quality Study detected concentrations of organochlorine and organophosophorus pesticides and heavy metals known to have toxicological effects to aquatic species. However, detection limits for other pesticides and metals of concern, such as mercury, DDT, dieldrin, endrin, and chlorpyriphos, were not low enough to detect concentrations of the compound at levels that are of concern to the health of aquatic organisms.

Although some sediment samples collected contained some detectable levels of environmental contaminants of concern to fish and wildlife, the distribution and concentrations of many contaminants in the lower Snake River system is still not well documented. Contaminant bioavailability from sediments is difficult to evaluate. The factors affecting the availability and toxicity of compounds to aquatic species are complex. Bioavailability of sediment-bound contaminants is a chronic exposure problem that cannot be determined by bulk-sediment analysis or elutriate testing alone (Cain, 1989). Bulk-sediment analysis does not take into account the potential changes in toxicity of compounds influenced by changes in the environment such as the drawdown alternative or physiological modifications within organisms. As the water chemistry changes during an event such as the drawdown, the chemistry of the sediment bound contaminants is also altered. This alteration of water and sediment chemistry may increase the bioavailibility of some contaminants to the aquatic environment. In addition, elutriate testing of sediments is designed to analyze the concentrations of water soluble compounds and does not evaluate the nonsoluble compounds bound to the sediment. Therefore, it is difficult to make a determination of the potential effects to the aquatic environment with existing information and without further investigation.

The time of year for initiating the Natural River Drawdown Alternative is also important. Toxicological effects to organisms are likely to be greatest should they become exposed to contaminated water or sediment during sensitive life stages. These life stages include migration, breeding, spawning, and early life stages. Health of the migrating and spawning Chinook salmon are of concern should a fall drawdown occur. Direct exposure to resuspension of contaminated sediments could cause adverse physiological effects to migrating fish, eggs, and fry/smolt. A spring or fall drawdown could also expose migrating birds and waterfowl to potentially toxic water and sediment.

Implementation of the Natural River Drawdown Alternative will redistribute sediments altering the morphology and water quality of the lower Snake River. The removal of the four lower Snake River dams will release potentially contaminated water and sediment not currently available to organisms. Industrial and municipal practices within the lower Snake River basin have contributed, and continue to contribute, organochlorine and organophosphate pesticides, petroleum hydrocarbons, dioxins and furans, heavy metals, and PCBs to the system. Increased exposure to contamination from the drawdown alternative may affect organisms directly, bioaccumulate through the food chain, or alter the prey base.

Available data are insufficient to determine potential toxicological effects of the Natural River Drawdown Alternative to fish and wildlife. With existing information, it is not possible to determine the exact effects contaminants in the lower Snake River system may have on fish and wildlife resources. The following recommendations would assist in gaining a better understanding of any potential risks to organisms should the Natural River Drawdown Alternative be implemented.

Complete a report for the 1997 Lower Snake River Feasibility Study Sediment Quality Analyses. The report should include sample collection methods, composition of sediment samples, locations of sample sites, analytical methods, results, and discussion. Appropriate sediment management reports should be referenced, and exceedences in recommended management concentrations should be flagged.

Additional sampling of the sediments should occur to develop a better understanding of the distribution and concentrations of elements and compounds in the impounded sediments. Integrated depth sampling down to native sediment, where possible, in areas most likely to become resuspended during the drawdown, would provide the most useful analytical data. Analyses of sediment should include heavy metals; organochlorine, organophosphorus, and carbamate pesticides; PCBs; dioxins; furans; and, total petroleum hydrocarbons. Samples should be analyzed using appropriate detection limits sensitive enough for concentrations that may cause adverse effects to aquatic organisms.

In addition, toxicity tests should be performed and should include effects of a range of concentrations within realistic durations of exposure.

Bioassays, such as the H4IIE bioassay, could be applied for testing rather than a full analysis to measure dioxin-like compounds (dioxins, furans, and coplanar PCBs) activity. Detection limits of any bioassay should be no greater than one pg/g.

To establish existing concentrations of the compounds expected to be released from the lower Snake River reservoirs, baseline "pre-drawdown" sediment sampling should occur in the McNary Pool where the bulk of impounded sediment is predicted to be deposited.

Gather additional data to address how interdependent and interrelated actions of the drawdown could impact the lower Snake and Columbia rivers contaminant loading.

Consider resuspension of contaminated materials as a point source discharge. Estimate the additional loading of DDT and metabolites, PCBs, and dioxin-like compounds (dioxin, furan, and planar PCBs), metals, organochlorine and organophosphorus pesticides, and petroleum hydrocarbons by determining the total amount of each contaminant (based on concentrations from chemical analysis on samples from a set amount of material) within the total amount of material to be resuspended. Report estimates to the appropriate state environmental quality personnel to determine if additional loading would violate current water quality standards for the lower Snake and the Columbia rivers.

10. Preliminary Recommendation

It is clear in our assessment that the Natural River Drawdown Alternative would provide many more benefits to fish and wildlife and their habitats than the other three alternatives in the area of the four lower Snake River dams. We believe this alternative would best increase survival of juvenile anadromous fish migrating through the area of the four lower Snake River dams. Additionally, it would significantly increase the area of spawning and rearing habitat for Snake River fall chinook, a threatened species. Furthermore, it is the only alternative that addresses restoration of natural or near natural riverine conditions which would produce a myriad of positive influences on natural processes and fish and wildlife. Therefore, based on our biological evaluation of the four alternatives' effects on fish and wildlife resources, the USFWS concludes that the benefits to fish and wildlife from the Natural River Drawdown Alternative exceed the benefits provided by the other alternatives. Again, as discussed in the Executive Summary, we intend to include additional information in the final FWCAR to evaluate the four alternatives within the broader context of all Hs, and will provide our final recommendations at that time. The following synopsis of the effects of the four alternatives provides additional rationale for our preliminary recommendation.

10.1 Existing Systems Alternative

The Existing Systems Alternative would continue the ongoing program with planned structural improvements and operations according to NMFS's 1995 Biological Opinion and 1998 supplement. Some improvement in juvenile and adult fish passage would occur, but conditions that lead to passage problems at the dams and through reservoirs would continue.

10.1.1 Anadromous fish

- Controlled spill at dams in the spring and transportation of fish during the summer would be required for juvenile fish migration.
- Flow augmentation would continue to be required with existing volumes or increased volumes of water. Summer drawdown of Dworshak Reservoir would continue, as would summer flow augmentation from Upper Snake River and Hells Canyon projects.
- Existing losses of fish during their passage through the lower Snake River would continue or be slightly reduced with planned structural improvements.
- Continued operation and maintenance of passage facilities for adult and juvenile fish would be required.
- Lower Snake River Fish and Wildlife Compensation Plan (Comp Plan) fish hatcheries and associated facilities and operations would continue to be required in the foreseeable future and would continue to fail meeting compensation goals.
- Lamprey passage needs would not be addressed.
- Water quality conditions would remain the same unless measures to improve contributing factors are implemented.
  - Adult and juvenile salmonids migrating in the spring would be exposed to extremely high and potentially lethal levels of gas supersaturation caused by uncontrolled spill, such as can occur during the spring freshet.

- The water temperature regime in the lower Snake River would improve little unless temperature control is provided at the Hells Canyon projects.

10.1.2 Resident fish

- Native fish species would continue to prefer the 'more riverine' segments of the reservoirs, such as the tailraces immediately below the dams and the old river channels; as reservoirs age, these areas would become more limited.
- White sturgeon would continue to face passage problems at the four dams, continuing an artificial partial segregation of this population.
- Non-native species would continue to use the warmer, slower, backwater areas created along the margins of the reservoirs.
- Northern pikeminnow, smallmouth bass, and channel catfish would continue to be significant predators of juvenile fall chinook salmon.
- Gas supersaturation during spill would continue to affect resident fish species, perhaps adversely.
- The resident fish mitigation goal for construction of the four lower Snake River dams was replacement of 67,500 angler days. This is accomplished by stocking 86,000 lbs of catchable rainbow trout annually, is considered successful, and would need to continue.
- Anglers fishing the lower Snake River reservoirs overwhelmingly prefer steelhead, but of those seeking resident fish, channel catfish, smallmouth bass, and rainbow trout would remain the preferred species.
- Resident fish sport harvest would continue to be dominated by crappies, smallmouth bass, channel catfish, and rainbow trout.
- Invertebrate fauna, although currently high in biomass, would continue to have little diversity and be dominated by worms, midges, and crayfish.
- The threat of a zebra mussel invasion is likely. They can clog fish passageways and their sharp edges would injure and descale smolts which come in contact with them.

10.1.3 Terrestrial Resources

This alternative would have no measurable effect on terrestrial resources. By the same token, it would not provide the opportunity for any benefits to these resources.

- Riparian corridors would continue to be disjunct and dominated with non-native species mainly in artificial islands maintained with irrigation.
- Intensive management efforts would continue to maintain wildlife habitat and food plots in limited areas.
- Size and structural complexity of riparian vegetation would continue to develop slowly.
- Mitigation for wildlife losses from the construction of the four dams would remain at about 75 percent of the estimated losses.

10.2 Maximum Transport of Juvenile Salmon Alternative

10.2.1 Anadromous fish

- This alternative would have similar effects to those of the Existing Systems Alternative.
- Maximum transport would result in a slight increase in the number of juvenile salmonids that are transported. The overall effect of this increase would depend on the survival of transported fish.
- Maximum transport would not increase the number of summer migrating (primarily fall chinook) juvenile salmonids that are transported from the lower Snake River. Under present operations, nearly all summer migrants that are collected are transported.
- There is presently uncertainty about the relative survival of transported fish compared to those that are not transported.
- Continued operation and maintenance of passage facilities for adult and juvenile fish would be required.
- Lamprey passage needs would not be addressed.
- Involuntary or forced spill, that can produce extremely high and potentially lethal levels of total dissolved gas, would continue. Adult and juvenile salmonids migrating in the spring would be exposed to these high levels of total dissolved gas.
- Water quality conditions would remain the same unless measures to improve contributing factors are implemented.
- The water temperature regime in the lower Snake River would improve little unless temperature control is provided at the Hells Canyon projects.

10.2.2 Resident fish

This alternative would have little or no effect on resident fish species, resident sport fishing, and invertebrates. All bullets listed for the Existing Systems Alternative for resident fish and invertebrates apply to this alternative as well.

10.2.3 Terrestrial Resources

This alternative would have no measurable effect on terrestrial resources. All bullets listed for the Existing Systems Alternative for terrestrial resources apply to this alternative as well.

10.3 Surface Bypass/Collection Alternative

The surface bypass/collection system at Lower Granite Dam is a prototype of a concept that is still being tested. It could potentially meet juvenile salmon fish passage efficiency goals for the region if it attained the performance of the surface bypass at Wells Dam.

10.3.1 Anadromous fish

- Studies to date indicate that the Surface Bypass/Collection prototype alone has met neither the Wells Dam surface bypass performance nor fish passage efficiency goals.
- Studies on the prototype will not be completed until 2000.
- Existing study information indicates that Surface Bypass/Collection would require:

  - Continued use of the existing screen and fish bypass system and the behavioral guidance system (steel curtain) to divert juvenile salmonids successfully
  - The use of existing screen and fish collection facilities plus spill to meet fish passage efficiency goals
  - Substantial reduction of the volume of water after diversion by the surface collector if fish are to be directed into a bypass system for transportation (No agreement exists in the region that this can be technologically accomplished.)
- If feasible, surface collection may take several years to become operational to meet regional standards. For example, the Wells Dam surface bypass required 12 years to become successful.
- This alternative does not address migration of lamprey.
- Structural and operational features of the Existing Systems Alternative would still be required.
- Uncontrolled spill at the lower Snake River dams during high flow periods would continue to produce excessively high TDG.

10.3.2 Resident fish

This alternative would have little or no effect on resident fish species, resident sport fishing, and invertebrates. All bullets listed for the Existing Systems Alternative for resident fish and invertebrates apply to this alternative as well.

10.3.3 Terrestrial Resources

This alternative would have no measurable effect on terrestrial resources. All bullets listed for the Existing Systems Alternative for terrestrial resources apply to this alternative as well.

10.4 Natural River Drawdown Alternative

10.4.1 Ecosystem restoration

Natural river drawdown would allow the restoration of riverine conditions along over 225 km (140 miles) of the lower Snake River. While it would not address all problems with Snake River salmon and steelhead stocks, it would restore near natural or "normative" channel morphology, ecosystem processes, and associated benefits on a landscape scale within the area of the four lower Snake River dams. The Corps (Technical Appendix H, Fluvial Geomorphology) found that since the lower Snake River was a partially alluvial system that was characterized by armored cobble/gravel bed material and areas of bedrock, it is reasonable to assume that pre-dam bathymetry approximates what would occur in the long term following dam breaching. Therefore, the physical condition of the river channel (channel morphology) should be able to return to a near-natural condition, with differences occurring at small scales.

- While flows originating in the upper Snake River Basin and the North Fork Clearwater would still be controlled by dam operations at Hells Canyon Complex and Dworshak dams, a major portion of the basin would become completely unregulated, allowing natural rhythms of spring runoff to occur.
- A more natural flow regime would help maintain and restore the timing, variability, and duration of floodplain inundation and associated benefits for wetlands and other habitats.

- A network of complex and interconnected habitats would be re-established, including:
  - A variety of aquatic habitats
  - A functional floodplain
  - A functioning riparian zone with native vegetation
  - Restored physical integrity of aquatic systems, including shorelines, banks, and bottom configurations
- Water temperature regimes would improve with a riverine system.
- Riverine-based, high-quality food supply, to which native aquatic organisms have been adapted, would be restored.
- Properly functioning riparian zones, which provide sources of food and habitat for many aquatic and terrestrial species and help improve water quality, would be restored.

While restoration of more natural flow and temperature regimes in the lower Snake River would immediately follow drawdown, restoration of other ecosystem components and processes would take several years to several decades. Some effort would be needed to ensure natural processes can function as naturally as possible, but delineating specific habitat parameters and creating artificial habitat should not be necessary. For example, sinuosity of the river- and pool-to-riffle ratios should be dictated by fluvial geomorphology processes. This system should be self- maintaining once established.

10.4.2 Anadromous fish

10.4.2.1 Short-term Effects

- Short-term effects could be adverse, but they can be mitigated.
  - Resuspended sediment and high turbidity immediately following dam breaching may cause direct mortality of anadromous fish and sedimentation may adversely affect existing fall chinook redds (likely 10 or less).
  - Adult fish migration would be blocked by drawdown work.
  - Adult fish entry into tributaries would be blocked during drawdown until streams eroded a channel through their deltas to the Snake River.
  - Fish could be stranded or entrapped during drawdown operations.
  - Following breaching, adult salmon and steelhead would have unhindered migration through the lower Snake River.

10.4.2.2 Long-term Effects

- Adult salmon and steelhead would have unhindered migration through the lower Snake River.
- Breaching could eliminate the few fall chinook redds that now occur in the tailraces of Lower Granite, Little Goose, and Lower Monumental dams; however, up to 1,437 ha (3,550 acres) of fall chinook spawning habitat could be restored.
- Juvenile salmonids would have unimpeded migration through the lower Snake River, shortening travel times and increasing their survival.

- Improved migration conditions for migratory fish could reduce or eliminate the need to augment streamflows in the lower Snake River.
- This is the only alternative with promise for improving smolt to adult returns enough for Comp Plan mitigation compensation goals to be realized.
- Analyses by NMFS and PATH indicate that the Natural River Drawdown Alternative has a greater probability of recovery and survival for spring/summer chinook, steelhead, and fall chinook.
- Riverine rearing habitat for juvenile fall chinook salmon would be restored in the lower Snake River. About 312 ha (770 acres) of preferred rearing habitat and about 257 km (160 lineal miles) of suitable shoreline habitat could be provided.
- Injury and mortality caused by passage through the existing screen and bypass systems or the turbines would be eliminated.
- Riverine conditions would provide a more complex environment of riffles, pools, and rapids, increasing the diversity of aquatic invertebrate food items.
- Natural river drawdown would allow for unimpeded migration by lamprey.
- Natural river drawdown would improve at least some aspects of water quality in the lower Snake River in the long term.
  - Spill and its accompanying high TDG would no longer occur, and safer conditions for fish and other aquatic life would be present.
  - A free-flowing river would dissipate gas supersaturated water produced by uncontrolled spilling at Hells Canyon and Dworshak dams.
  - Free-flowing river conditions could increase the ability to meet temperature standards in the lower Snake River through releases from Dworshak Dam.
- Currently, it is unknown how contaminants in sediments, which would be resuspended and redeposited following drawdown, would potentially affect aquatic life. While some sediment samples have contained detectable levels of a few environmental contaminants, additional investigations would be needed to better characterize contaminants in the sediments, their bioavailability to aquatic organisms, and the potential adverse impacts, if any, they may pose to aquatic organisms.

10.4.3 Resident fish

10.4.3.1 Short-term Effects

- The most significant short-term effect of drawdown to both resident fish and invertebrates is the potential for stranding. Mitigation is described in the next section.
  - Most resident fish would be able to follow receding water levels; however, some fish would become stranded as pockets of water become isolated from the main channel. Juvenile fish, especially non-native fish which rear in the backwater areas, would be more likely to become stranded than adults.
  - Those invertebrate species that avoid desiccation by burrowing deeper into the substrate and those that would move too slowly to follow receding water levels would be lost.

- The loss of shallow, backwater areas would result in the loss of preferred spawning habitat for many non-native resident fish species.

10.4.3.2 Long-term Effects

- Most native resident fish species would benefit from returning the lower Snake River to a free-flowing river since most are broadcast spawners and depend on flowing water for successful reproduction.
  - White sturgeon sub-populations would no longer be artificially isolated and numbers would increase due to improved spawning and rearing habitat and increased food abundance.
  - Usage of the area by species that prefer cold water, such as bull trout, mountain whitefish, and rainbow trout, would increase as connectivity between tributaries is improved and water temperatures are cooler for prolonged periods.
  - Redside shiners, chiselmouth, peamouth, sculpin, and bridgelip suckers would benefit from restoration of a more riverine ecosystem.
  - Largescale suckers are habitat generalists and would decrease in abundance due to the loss of aquatic habitat associated with drawdown.
- Most non-native species would decrease in abundance from loss of their preferred shallow areas with little to no current and soft substrate.
- Predation by resident fish species on salmon and steelhead, especially the threatened fall chinook would decrease because 1) increased flow velocity would reduce predator/prey encounters; 2) associated increased turbidities would reduce effectiveness of predators which rely on sight; 3) earlier cooling of water temperature would decrease predator metabolism and effectiveness; and, 4) dam structures which currently give northern pikeminnow an advantage would be gone.
- Resident fish sport fishing would improve since populations of native species such as rainbow trout and white sturgeon would increase in abundance and populations of the non-native smallmouth bass and channel catfish would remain about the same.
- The ongoing rainbow trout mitigation program could be stopped when a properly functioning ecosystem became re-established.
- Invertebrate species diversity would increase dramatically:
  - Overall abundance of worms and midges would decrease.
  - Drift from the Snake River and major tributaries would provide a rich source of colonizers for the newly created flowing habitat.
  - Numbers of mayflies, caddis flies, and stone flies would increase.
  - Mollusc diversity would increase with molluscs currently persisting in the Hells Canyon Reach of the Snake River re-inhabiting areas downstream once cooler, faster water provides more suitable habitat than that which currently exists.
  - Crayfish density is likely to be similar or better than current conditions.

10.4.4 Terrestrial Resources

10.4.4.1 Short-term Effects

- Extensive foraging areas for several shorebird species would be created as water levels receded with the drawdown.
- A significant amount of riparian habitat would be lost (dessication and separation from water's edge) and converted to upland habitats.
- Some wildlife would be lost through direct mortality. (For example, smaller and less mobile species such as small mammals and amphibians would not survive the short-term loss of riparian, wetland and some upland habitats.)
- Some wildlife would be lost through indirect mortality. (For example, some wildlife would be exposed to predation when traveling from cover to the water's edge; more mobile species may attempt to disperse to nearby habitats which are already at or near carrying capacity; and the travel/migration corridor along the river may be reduced even further than that existing now.)
- There would be an opportunity for several weed species to spread rapidly along the river on exposed mud flats. The proposed implementation of aggressive revegetation and weed control measures would mitigate this impact.

10.5 Long-term Effects

Our analysis assumes that the Corps would actively manage its lands following drawdown to ensure habitat restoration is as complete as possible and would include such things as an aggressive weed control plan and revegetation measures being applied immediately following drawdown. It also assumes the Corps would continue to irrigate and manage current HMUs until riparian vegetation is well established (about 25 years).

- The riparian zone present before the dams were constructed (about 1,336 ha [3,300 acres] of woody riparian habitat) would eventually be restored.
- The quality and quantity of riparian habitat would likely be increased to a level above that which existed immediately before the dams were constructed, since sediments deposited in the reservoirs (much of it rich topsoil) would provide an excellent substrate for plant growth.
- Improved riparian habitat conditions would result in positive effects for several groups of wildlife (game birds, raptors, other non-game birds, big game animals, small mammals, and bats).
- Improved habitat conditions would also benefit some species of waterfowl, furbearers, amphibians and reptiles.
- Full mitigation for wildlife losses which occurred when the dams were constructed, mitigation for interim losses, and mitigation for wildlife losses associated with the Drawdown Alternative should all be easily attained.
- Most of the existing wetlands (about 121 ha [300 acres]) would be lost with a reduction or elimination of species which rely on them.
- Additional wetlands should develop in the new floodplain, as well as in the McNary Reservoir pool, from sedimentation following the drawdown. There is a potential for several hundred acres of wetlands to develop in the long term.

- There would be a loss of reservoir habitats and reduction or elimination of species that rely on them (for example, some waterfowl and gull species).

Tables 10-1 through 10-4 help to illustrate further the greater benefits the Natural River Drawdown Alternative would provide to fish and wildlife.

Table 10-1. Summary of Expected Effects of the Four Study Alternatives on Anadromous Fish

	Existing Systems & Maximum Transport	Surface Bypass/ Collection	Natural River Drawdown Collection
Reservoir Habitat	o	o	-
Riverine Habitat	o	o	+
Riparian Habitat	o	o	+
Spawning Habitat	o	o	+
Rearing Habitat	o	o	+
Juvenile Migration	+	+	+
Adult Migration	+	o	+
Dissolved Gas Reduction	+	o	+
Suspended Sediment	o	o	- initially, o long term
Water Temperature	+	o	+
Predation Reduction	o	o	+

10.6 Summary

As noted above, there would be both beneficial and adverse effects to fish and wildlife and their habitats from the various alternatives. The Existing Systems, Maximum Transport and Surface Bypass/Collection Alternatives would have very little effect, if any, on resident fish or terrestrial wildlife. However, the Natural River Drawdown Alternative would result in major changes to much of the lower Snake River and would significantly affect all species groups. The benefits to fish and wildlife resources in the area of the four lower Snake River dams from drawdown would exceed those provided by the other alternatives.

It is unlikely that the Existing Systems Alternative could improve existing conditions for migrating anadromous salmonids. Past operation of the existing system has been accompanied by a downward trend in wild Snake River salmon and steelhead. Furthermore, this alternative does not address lamprey or white sturgeon passage needs and would not benefit resident fish or terrestrial wildlife species.

The effects of the Maximum Transport Alternative would differ slightly from those of the Existing Systems Alternative. Maximizing transport of juvenile salmonids would increase the number of fish that are transported from the lower Snake River to the Columbia River downstream of Bonneville Dam. It would not increase the number of summer migrating fish that are transported since transportation of these fish is already maximized. The total number of Snake River fish that are transported would only increase moderately because the percentage of fish that are currently transported is high. Furthermore, this alternative does not address lamprey or white sturgeon passage needs and would not benefit resident fish or terrestrial wildlife species.

Table 10-2. Summary of Expected Effects of the Four Study Alternatives on Anadromous Fish

		Existing Systems & Maximum Transport	Surface Bypass/ Collection	Natural River Drawdown
Fall Chinook	Adult Immigration	o	o	+
	Adult Holding	o	na	na
	Spawning	o	na	+
	Incubation	o	na	+
	Emergence	o	na	+
	Rearing	o	na	+
	Juvenile Migration	+	+	+
Spring/Summer Chinook	Adult Immigration	o	o	+
	Adult Holding	o	na	+
	Spawning	na	na	na
	Incubation	na	na	na
	Emergence	na	na	na
	Rearing	o	na	na
	Juvenile Migration	+	+	+
Steelhead	Adult Immigration	+	o	+
	Adult Holding	na	na	+
	Spawning	na	na	na
	Incubation	na	na	na
	Emergence	na	na	na
	Rearing	na	na	na
	Juvenile Migration	o	+	+
Sockeye	Adult Immigration	o	o	+
	Adult Holding	na	na	na
	Spawning	na	na	na
	Incubation	na	na	na
	Emergence	na	na	na
	Rearing	na	na	na
	Juvenile Migration	o	+	+
Lamprey	Adult Immigration	o	o	+
	Adult Holding	?	na	+
	Spawning	?	na	+
	Incubation	?	na	+
	Emergence	?	na	+
	Rearing	?	na	+
	Juvenile Migration	o	?	+
Shad	Adult Immigration	o	o	-
	Adult Holding	o	na	-
	Spawning	o	na	-
	Incubation	o	na	o
	Emergence	o	na	o
	Rearing	+	na	-
	Juvenile Migration	+	+	+

Note: + is a positive effect; - is a negative effect; o is a neutral effect; na is not applicable; ? is an unknown effect.

Table 10-3. Summary of Expected Effects of the Natural River Drawdown Alternative on Resident Fish

Resident Fish Group	Spawning	Juvenile Rearing	Growth	Overall Abundance
Native species				
Sturgeon	+	+	+	+
Trout	o	o	o	+[1/]
Minnows	+	+/-	+/-	+
Suckers	+/-	+/-		+/-
Others	+/-	+/-		+/-
Non-native species				
Minnows (Carp)	-	-	-	-
Catfish/bullhead	+/-	+/-	+/-	+/-
Largemouth bass	-	-	-	-
Smallmouth bass	o	o	o	o/+[2/]
Other sunfish	-	-	-	-
Yellow perch	-	-	-	-

1/ This is because of increased overwinter habitat.

2/ Predictions for smallmouth bass populations vary from slightly increasing to staying about the same.

Table 10-4. Summary of Expected Effects of the Natural River Drawdown Alternative on Terrestrial Resources[1/]

Terrestrial Resources	Short-term Effects	Long-term Effects
Riparian Habitat	-	+
Upland Habitat	-/o	o
Game Birds	-	+
Waterfowl	-	+/-
Shorebirds	+	o
Colonial-nesting Birds	+/-	-
Raptors	-	+
Other Non-game Birds	-	+
Big Game Animals	-	+
Small Mammals	-	+
Bats	-/o	+
Furbearers	-	+/-
Amphibians and Reptiles	-/o	+/-

1/ This assumes retention of current irrigation at the HM-Us. Otherwise, negative effects would be more severe in most cases, at least for the short term.

The Surface Bypass/Collection Alternative involves a prototype of a concept that is still being tested. Studies to date have not shown that it has met fish passage efficiency goals. Surface bypass cannot achieve high fish passage efficiencies alone, and it would need existing or improved fish screen and bypass systems. Also the Surface Bypass/Collection Alternative would not improve migration rates or survival of juvenile salmonids in the reservoirs. Finally, this alternative would not be likely to improve lamprey or sturgeon migration and would not affect resident fish or terrestrial wildlife.

The Natural River Drawdown Alternative would restore near natural or "normative" riverine ecosystem conditions to over 225 km (140 miles) of the lower Snake River. Some initial measures may be needed to help restore these conditions (for example, weed control), while much of the restoration and maintenance of these conditions would occur naturally. Also, once established, this system would virtually maintain itself and need little human assistance in the future, similar to the free-flowing Hell's Canyon Reach of the Snake River.

The Natural River Drawdown Alternative would improve migration conditions for anadromous salmonids and other migratory fishes through the area of the four lower Snake River dams, restore riverine habitat and spawning habitat for fall chinook salmon, and improve water quality. Returning the lower Snake River to a free-flowing river would benefit most resident fish native to the area, while species introduced to the system that have capitalized on the reservoir habitat would decrease in abundance. Other non-native species that typically do well in river environments, such as smallmouth bass and channel catfish, would likely either increase or not be greatly affected. Overall, sportfishing in the study area would be enhanced. With the restoration of a functioning riparian zone and floodplain, habitat critical for many wildlife species would develop and be maintained in the long term.

While breaching the lower Snake River dams would have some short-term adverse impacts to fish and wildlife resources, the long-term benefits would far outweigh the potential impacts. Also, some of the potential impacts could be mitigated. Measures recommended for mitigation, monitoring, and enhancement are included in the next sections of the FWCAR. These would help ensure that adverse impacts would be avoided, minimized, and compensated and that conditions would be monitored to facilitate adaptive management.

11. Mitigation Measures

11.1 Anadromous Fish

11.1.1 Existing Systems Alternative

11.1.1.1 Lower Snake River Fish and Wildlife Compensation Plan

As mentioned earlier, the Compensation Plan was enacted in response to declining salmon and steelhead runs in the lower Snake River and terrestrial wildlife losses from reservoir construction. The plan authorized the use of artificial production methods to mitigate salmon and steelhead losses following the construction of the four dams on the lower Snake River. Eleven hatcheries, 12 associated satellite facilities, and a pathology lab were constructed or modified in Washington, Oregon, and Idaho to address Compensation Plan production needs. The Compensation Plan was somewhat unique in that its focus was on replacing losses of returning adults to the project area for fall chinook (that is, above Ice Harbor Dam) or above the project area for spring/summer chinook and steelhead (that is, above Lower Granite Dam). The program's smolt production target was based on the estimated proportion of Snake River fish that would be lost because of the project (about 48 percent of the Snake River run), the approximate number of smolts required to replace estimated adult losses, and the smolt to adult survival (Herrig, 1990).

In February 1998, a Compensation Plan symposium dealing with current status, evaluation, and adaptive management alternatives was held in Boise, Idaho. At this symposium, numerous status and evaluation reports from state, Indian, and USFWS comanagers were presented. The symposium presentations confirmed that the Compensation Plan has not met its compensation goals for chinook salmon. While some steelhead programs have met their adult return goals, most of them have been unsuccessful in reaching identified compensation goals on a annual basis (USFWS, 1998). In addition to the limited success of the LSRCP to compensate for hydrosystem operations, the recent listings of steelhead, bull trout, and Snake River sockeye, spring/summer chinook, and fall chinook under the ESA have required the Compensation Plan to modify programs at each facility to avoid jeopardy or minimize effects on rapidly declining listed populations.

An important outcome of the recent symposium was the identification of factors limiting the overall success of the Compensation Plan. In all cases, very poor smolt to adult survival was the reason for a program's inability to meet its individual compensation goals. This poor survival is directly tied to the operation of the hydroelectric system on the lower Snake River.

It is unlikely that Compensation Plan compensation goals will be reached with the current hydrosystem in place. The continuation of the status quo as outlined under the Existing Systems Alternative may not improve the current situation, making the attainment of the original Compensation Plan goals impossible.

The Maximum Transport Alternative would result in similar probabilities of survival and recovery as the Existing Systems Alternative. Compensation Plan goals would not be attained under this alternative unless returns of adult salmon and steelhead that were transported as juveniles improve markedly. Adult returns of transported fish have been far less than the 2 to 6 percent range determined necessary for recovery.

The implementation of the Surface Bypass/Collection Alternative relies on conceptual and theoretical improvement of passage and survival around each of the facilities. While it is difficult to speculate on the effects of this alternative on Compensation Plan program, it is unknown if it would significantly improve juvenile survival or allow realization of Compensation Plan adult goals in the near future.

The best hope of reaching the original Compensation Plan compensation goals is the implementation of the Natural River Drawdown Alternative. The anticipated juvenile survival improvement would allow the Compensation Plan to meet its compensation goals, assist in recovery and restoration, and might reduce or eliminate compensation needs.

11.1.1.2 Biological Opinion Operations

Operations under the NMFS 1995 Biological Opinion and 1998 Supplemental Biological Opinion are mitigation measures that are intended to offset the adverse impacts of the operation of the lower Snake River dams and reservoirs. Implementation of these measures is aimed at preventing extinction of the listed stocks of Snake River salmon and steelhead. These measures include operation and maintenance of the juvenile fish screen and bypass systems and adult fish facilities, spill, flow augmentation, temperature control, juvenile fish transportation, control of TDG production, operation of reservoirs at minimum operating pool, and operation of turbines within 1 percent maximum efficiency. Continued improvement of the system for fish passage would occur under the Existing Systems Alternative.

It would be necessary to continue project operations with these measures in place throughout the life of the lower Snake River projects. Operation with these measures would require continued monitoring and maintenance of all fish passage facilities to ensure that fish passage criteria are being met. Continued modification of the existing system should also be implemented to improve fish passage conditions based on the results of future research.

11.1.1.3 Reduction of Predator Habitat

Much of the shoreline of the lower Snake River reservoirs has been covered with rock riprap to stabilize erosion. Riprap has been found to be a preferred habitat of smallmouth bass which is a predator on juvenile salmonids. Subyearling fall chinook salmon are especially vulnerable to predation because they tend to inhabit shallow waters early in life and are exposed to smallmouth bass as they pass riprapped areas. Curet (1993) observed that subyearling fall chinook that were rearing along the shoreline of Lower Granite Reservoir strongly preferred sandy bottomed areas and strongly avoided riprapped habitat. Curet also found that smallmouth bass consumed about 6 percent of the subyearling chinook salmon migrating through Lower Granite Reservoir and less than 0.02 percent of the steelhead and yearling chinook migrants. Riprap also provides poor habitat for food organisms preferred by subyearling fall chinook. Riprap is also a poor substrate for riparian vegetation.

Dredging has been proposed at several locations in the lower Snake River reservoirs to restore authorized navigation depths. The USFWS has previously recommended to the Corps that dredged material be placed on riprapped areas. This would reduce available smallmouth bass habitat and provide more shallow sand bottomed habitat for fall chinook, as well as potential sites for establishing riparian vegetation. The Corps should investigate the placement of dredged material at selected riprapped shoreline sites. It would likely have to include some vegetation establishment, erosion control matting, or other measures to protect portions of the sites from wave erosion.

11.1.1.4 Lamprey Passage

Passage routes for adult lamprey migrations at the lower Snake River dams should be determined. After this determination, these routes should be examined for any physical obstructions or activities that are inhibiting lamprey passage. All obstructions and/or activities that may be inhibiting the upstream passage of adult lamprey at lower Snake River dams should be removed.

Dam facilities and operations should also be evaluated to determine if they safely and effectively pass juvenile lamprey. If delays in migration, injury, or mortality to juvenile lamprey are observed, then measures to reduce such problems should be developed and implemented.

11.1.2 Maximum Transport of Juvenile Salmon Alternative

The Maximum Transport Alternative would expand the transportation efforts currently being implemented for the Existing Systems Alternative. The mitigation measures described for the Existing Systems Alternative would apply to this alternative.

11.1.3 Surface Bypass/Collection Alternative

The Surface Bypass/Collection Alternative, like the Existing Systems Alternative was developed as a mitigation measure that is designed to offset the adverse impacts to juvenile salmonids at the Snake River dams. All of the mitigation measures that have been described for the Existing Systems Alternative would be required for the Surface Bypass/Collection Alternative.

11.1.4 Natural River Drawdown Alternative

The Natural River Drawdown Alternative was also developed as a mitigation measure, but is one which would involve major changes to the existing conditions of the lower Snake River dams and reservoirs. Dam breaching would cause significant changes to anadromous fish habitat. Immediate effects to water quality and physical habitat could be detrimental unless proper steps are taken to avoid or offset them.

Mitigation of the immediate adverse impacts caused by dam breaching is addressed in detail in Technical Appendix A (Corps, 1999). The following is a summary of impacts and mitigative measures necessary to offset those impacts.

11.1.4.1 Turbidity and Sedimentation Effects

Adverse effects of high turbidity and sedimentation should be reduced by timing of the drawdown work and by drawing down the reservoirs in stages. The initial effects of drawdown on anadromous fish should be reduced by conducting drawdown work when the fewest juvenile and adult fish are present. This time would be during the winter. Future effects of sedimentation may be lessened by drawing reservoirs down in several stages and allowing sediments to settle between the following pool lowering operations. This would allow the remaining sediments to stabilize and possibly become revegetated before a future high flow event occurs.

11.1.4.2 Timing of Dam Breaching Work

The Corps presently plans to conduct dam breaching activities beginning in August. This work is expected to take from 60 to 90 days. Work during this time period would occur during the peak of adult fall chinook salmon and steelhead migration in the Snake River. Work during the August to late November period would also affect juvenile salmonids, particularly subyearling fall chinook and

sockeye salmon. The Corps has indicated the desire to conduct work during this period to reduce the risk of high streamflow events which begins to increase in January. Preparatory work should be conducted during the early part of the proposed work period so that actions that have the greatest impact, such as the final dam breaching, should take place after late November when the fewest fish would be present.

11.1.4.3 Blockage of Adult Fish Passage at the Dam Sites

Excavation and construction during the upstream migration time of adult anadromous fish would require that fish guidance and collection measures be undertaken to ensure that adult fish migration is not delayed or stopped. Impacts to migrating adult salmonids could be lessened by sequentially breaching the dams starting with Lower Granite Dam and continuing downstream. Preliminary work should be conducted during the main period of fall chinook and steelhead migration. Final breaching of the dams should be done after the main migration period. Adult fish should be collected at Little Goose Dam, which is upstream of the Tucannon River mouth and Lyons Ferry Hatchery, and then transported and released upstream of Lower Granite Dam. This would allow fish to return to Lyons Ferry Hatchery and the Tucannon River.

Fall chinook salmon, whose spawning run is nearing completion in November, would benefit more by this operation than steelhead, which continue to migrate upstream into December. In addition, steelhead cease their migrations when water temperatures drop below 39°F (Stabler, 1981) and overwinter in the Snake River reservoirs. These fish would be adversely affected by winter breaching and drawdown operations.

It may also be necessary to add pumps to provide sufficient water and chutes to pass fish to the lowered reservoirs to keep the fish ladders operable during the construction period (Raytheon Infrastructure, Inc., 1998).

11.1.4.4 Blockage of Adult Fish Entry into Snake River Tributaries

Sediment accumulations that now exist where tributaries enter the reservoirs are expected to be flushed out soon after drawdown occurs. However, measures should be taken to assure that anadromous fish passage is not blocked. Channels could be excavated or dynamited through the sediment deposits down to the original streambed elevation of the tributaries as the reservoirs are drawn down before actual dam breaching takes place. Such activities should be closely coordinated with state, Federal, and Indian fish passage staff. This also applies to resident fish which spawn in tributaries.

11.1.4.5 Stranding of Fish During Drawdown

Although relatively few stranded salmonids were found during the 1992 test drawdown of Lower Granite Reservoir, potential stranding should be reduced by drawing down the reservoirs slowly. Trained staff should be employed to monitor potential stranding areas during the actual drawdown and to salvage stranded salmonids.

11.1.4.6 Lyons Ferry Hatchery Operations

Lyons Ferry Hatchery is a major contributor to the recovery program for Snake River fall chinook salmon. It also produces steelhead that are stocked in the many Snake River tributaries. Continued operation of this hatchery would be essential to future efforts to recover the Snake River population of fall chinook salmon. Drawdown to the natural riverbed elevation would require construction of an

extension to the existing fishway for adult salmon and steelhead that return to the hatchery. Facilities used to convey juvenile fall chinook and steelhead from the hatchery to the Snake River would also require modification. The water supply system for this hatchery would also have to be changed to ensure that a reliable water source can be maintained. This would involve major reconstruction of several miles of water supply pipeline.

11.2 Resident Fish

As with anadromous fish, some resident fish will become stranded. Rescue attempts should be made where significant numbers of fish are stranded in areas which are safe to work (that is, where sediments are solid enough to be walked on safely). Stranded fish could be moved to areas which would not become isolated from the main Snake River as drawdown continues.

However, for the most part, mitigation for resident fish species would not be necessary. Although there would be resultant losses in fishing opportunity for the sport angler on resident species, these species are not native to the lower Snake River and would not be any worse off than had the facilities never been constructed. Additionally, angling is likely to improve for sport species adapted to river environments: sturgeon, rainbow trout, mountain whitefish, smallmouth bass, and channel catfish.

An exception to this is the ongoing mitigation for rainbow trout. This program was initiated to mitigate for losses due to the construction of the lower Snake River facilities. Although removing the facilities would hopefully reverse those losses, it would take a few to several years for the environment to stabilize. At a minimum, the rainbow trout program should be continued until this occurs. However, at least some, if not all of the release sites used in the past would be permanently dewatered. New release sites, including tributaries and any adjacent lake areas, should be developed in cooperation with WDFW, IDFG, and the Corps.

11.3 Invertebrates

An intensive mollusc survey should be carried out at sites which may still harbor components of the native mollusc community. These sites are most likely to occur near tailraces and tributaries. Based on this survey, a plan should be developed to identify sites where native species would be stranded with a natural river drawdown and rescue attempts made to return live individuals to portions of the lower Snake River which would not become permanently isolated from the main flow of water.

11.4 Terrestrial Resources

11.4.1 Mitigation for Drawdown Impacts

If the Natural River Drawdown Alternative is selected, it is imperative that a riparian zone and functioning floodplain be restored along the lower Snake River. This would be critical to the protection of the very resource the Corps' Feasibility Study was designed for: anadromous salmonids. Aside from salmon, many other fish and wildlife species would require, or at least directly benefit from, restoration of a properly functioning riparian zone and floodplain following drawdown. Furthermore, it would be important to maintain a properly functioning upland buffer adjacent to the riparian/floodplain zone to fully restore and maintain the Snake River, its riparian zone, and associated fish and wildlife resources.

An interagency mitigation team should be established, with participation by at least the Corps, WDFW, and USFWS. This would involve a significant effort, and the Corps would have to plan on full time participation.

While some riparian and upland restoration would occur naturally, there would be a need for active management efforts. One of the priority management efforts would be to implement aggressive weed control immediately following drawdown. Detailed management recommendations would have to be developed by the mitigation team being formed and chaired by the Corps.

Mitigation for impacts to terrestrial resources resulting from the proposed drawdown should involve three main points: 1) using HEP to evaluate habitat impacts and for guiding mitigation efforts to benefit wildlife resources, 2) determining impacts from the drawdown, such as from desiccation and loss of habitat existing along the reservoir shorelines, and 3) restoring a properly functioning riparian zone and functioning floodplain along the new Snake River channel. Continuing to use HEP to evaluate impacts and guide mitigation would be prudent since it is a proven methodology that has stood up in court and would provide continuity with previous HEP analyses. It is usually advantageous to attempt to determine potential habitat losses and gains before a particular action takes place. While that should occur with this case, it is likely that adjustments would have to made to these estimates in the future due to weather conditions, for example. Therefore, any mitigation plan developed for the proposed drawdown should allow for ample adaptive management strategies.

Because of the need for some active management actions, the possible retention of irrigation and management of HMUs, and the need for adaptive management strategies, project lands should be retained by the Corps until restoration and mitigation have been completed.

Irrigated HMUs should continue to be irrigated and maintained following a drawdown. They should be maintained at least until all habitat credits for the Compensation Plan have been gained and habitat has been adequately established along the new river corridor. Furthermore, the development of habitat corridors between HMUs and the river and newly developing riparian zones would further reduce wildlife impacts in the long term and reduce mitigation requirements.

Once restoration and mitigation actions have been completed, the current project lands should remain in public ownership. Reasons for retaining lands in public ownership include the following:

Since the concrete portions of the dam and appurtenant facilities would be retained, it is logical to also retain the lands that would be needed if the dams are restored in the future.

Considerable expense and effort has been made in the development of habitat management units, parks, and other public facilities on project lands. Retaining the project lands in public ownership would help ensure they are maintained and the public continues to derive benefit from them.

There has been difficulty in the past locating adequate sites for mitigation activities, and a relatively large amount of unmitigated losses remain due to the original dam construction. Retaining the project lands in public ownership would help ensure a land base for fulfillment of Corps' mitigation responsibilities.

Maintaining these lands in public ownership should help ensure that maintaining a properly functioning Snake River system, including riparian zones, floodplains, and buffer areas, remains a high priority.

Techniques to successfully restore native vegetation along riparian/floodplain areas should be developed and tested, if the Natural River Drawdown Alternative is selected to help minimize establishment time.

To mitigate for poor wildlife travel conditions created by the loss of the waters edge adjacent to riparian habitat, travel corridors should be established through riprap at several locations. This should occur along some of the existing riprap locations and at new riprap sites. At existing sites, travel corridors may be created by simply moving some of the riprap which would no longer function with the drawdown in place. For new riprap, corridors could be created by placing fill material over the riprap in selected locations.

Impacts to upland habitat from stockpiling and temporary road construction during dam breaching activities should be minimized by creatively narrowing the footprint of the direct impacts wherever possible. Also, upland sites used for these activities should be those with the lowest habitat values (for example, croplands and degraded grassland) and habitats that cannot recover relatively easily (for example, high quality shrub-steppe) should be avoided.

11.4.2 Current Unmet Mitigation Needs

As described earlier, there are still unmet mitigation needs in the form of HUs that were estimated to be lost with inundation by the four reservoirs. Also, there is still a large gap in acreage of important habitat that was inundated and that which has been replaced to date. Additional work must still be done to improve habitat on facility and off-facility lands to attempt to improve HSI values and help achieve full mitigation for losses. However, an important step must be measured HEP analyses at each HMU and other facility lands to determine more precisely where the HU compensation balance currently stands and to understand where changes in management actions are warranted to improve HSIs and ultimately increase HU compensation.

Some of the principles and criteria used in determining management measures should be revisited. For example, while they do provide some habitat, the planting and maintenance of non-native species (such as, Russian olive) on HMUs and other lands should be phased out. More desirable native species should be substituted to help achieve communities more similar to those lost.

While the HMUs, as designed, are currently replacing some habitat values, they are not replacing some of the habitat components that are also important to fish and wildlife resources that formerly and currently use the Snake River system. Also, the HMUs currently provide islands of important habitat with little connection with other similar habitats. This lack of connectivity can adversely impact species that rely on habitat corridors for travel, migration, dispersal of young, and adequate genetic mixing. A more continuous riparian corridor of native vegetation along the shoreline, as occurred prefacility, should be encouraged to help provide this connectivity.

There are some fenced corridors scattered along the reservoirs. They allow cattle access down to the shoreline to obtain water. These cattle concentration areas have resulted in degradation of native vegetation, mainly mesic shrub habitat. Adverse impacts should be avoided by developing alternative watering sources or changing the corridors to protect existing woody vegetation and to allow replanting where possible.

Furthermore, as discussed earlier, while riprapping the shoreline has improved habitat for river otter, it can be a travel impediment for some animals attempting to reach the water. Some potential measures that should be investigated to rectify this problem include (1) covering riprap with dredged or other material as suggested above at selected locations, (2) modifying riprap at selected locations to improve travel by various species, and (3) constructing wildlife crossings over riprap at selected locations.

Measured HEP analyses at each of the HMUs may show that some areas will never develop sufficiently to allow habitat values (HSIs) to reach or even come close to projected levels. This would suggest that the criteria that HUs originally projected to be gained by management activities would be fully credited to the Compensation Plan immediately following completion of habitat development (USFWS, 1991), are invalid. Measured HEP analyses should be used to determine more accurate projections of future HSIs with habitat developments, with possible additional changes in the compensation balances.

The LOA should be amended to include additional mitigation for annualized losses because of long delays in replacing and restoring lost habitat values.

12. Monitoring Recommendations

12.1 Anadromous Fish

12.1.1 Existing Systems Alternative

12.1.1.1 Salmonids

Numerous studies that involve monitoring and evaluation of existing operations and facilities of the lower Snake River dams are being conducted under implementation of the NMFS 1995 Biological Opinion and 1998 Supplementary Biological Opinion. These studies should continue if the Existing Systems Alternative is selected.

The riprapped shorelines that are used for dredged material disposal sites should be monitored to determine if smallmouth bass use has decreased and if subyearling chinook use has increased. These sites should also be monitored to determine the rate at which they become revegetated and the species of plants that become established.

Presently, TDG data are available for the Snake River upstream to Lewiston, Idaho, and in the Clearwater River system at Dworshak Dam and Peck, Idaho. There are no real-time data for the Snake River upstream of Lewiston, Idaho. Lack of data for the Snake River upstream from Lewiston, Idaho makes efforts to control TDG impacts on juvenile salmonids in the Hells Canyon reach difficult. TDG should be monitored in the Hells Canyon reach so that effects on incubating, rearing, and migrating salmonids can be determined.

Temperature monitoring should continue under future flow augmentation/temperature control programs that involve releases from Dworshak and Brownlee reservoirs. Data that are collected could be used for future flow and temperature modeling efforts that would be intended to improve conditions for juvenile and adult salmonids.

12.1.1.2 Pacific Lamprey

Monitoring of lamprey passage at all lower Snake River dams should begin immediately to obtain an estimate of the present abundance of lamprey in the Snake River System.

Research to address critical uncertainties related to impediments to lamprey passage at Snake River dams should be implemented.

Lamprey passage should be monitored to determine lamprey guidance efficiencies at juvenile fish passage facilities at the lower Snake River dams.

Studies should be conducted to evaluate adult and juvenile lamprey migration and to identify possible passage impediments and necessary improvements.

12.1.2 Maximum Transport of Juvenile Salmon Alternative

The operations of the lower Snake River dams under the Maximum Transport Alternative would be similar to those in effect under the Existing Systems Alternative. Monitoring conducted under the Existing Systems Alternative would apply to the Maximum Transport Alternative.

12.1.3 Surface Bypass/Collection Alternative

12.1.3.1 Salmonids

The prototype SBC is presently being studied to determine the feasibility of this concept in improving juvenile fish passage at Lower Granite Dam. These studies include hydroacoustic and radiotag monitoring of fish movement and use of the SBC, tracking of adult fish migration, and predation. Such studies should continue if the Surface Bypass/Collection Alternative is chosen to be implemented to evaluate the effectiveness of the full-scale SBC. The SBC should be monitored throughout the life of the facility to ensure that passage and performance criteria are being met. Similar studies and monitoring would be necessary at each of the facilities where a SBC is installed.

Monitoring and evaluation that is now being conducted at all of the lower Snake River facilities should be continued for those facilities that would remain in place and for those operations that would continue. These would include both adult and juvenile fish passage facilities.

12.1.3.2 Pacific Lamprey

Lamprey studies proposed for the Existing Systems Alternative should be included in any studies for the Surface Bypass/Collection Alternative.

12.1.4 Natural River Drawdown Alternative

12.1.4.1 Spawning and Rearing Habitat

Natural river drawdown is expected to restore fall chinook salmon spawning habitat in the lower Snake River. Monitoring should be started immediately after drawdown to determine when fall chinook salmon spawning habitat becomes suitable or established in the restored Snake River. Physical characteristics, including substrate size composition, water velocity, slope, intra-gravel water flow, and temperature, should be monitored.

Biological monitoring should be conducted to verify that suitable spawning habitat has been restored and is being used. Annual spawning surveys should be initiated when physical monitoring shows that suitable conditions for spawning have been established. Biological monitoring should continue through incubation and emergence to verify the success of reproduction.

12.1.4.2 Juvenile Reach Survival

Studies are now being conducted to determine the survival of juvenile salmonids as they pass through the lower Snake River system of dams and reservoirs. Natural river drawdown should increase the survival rates of juvenile salmonids during downstream migration. These ongoing studies could be modified and continued to address survival of Snake River salmonids by examining their survival rates through the free-flowing lower Snake River to McNary Dam from release sites that are now being used for the existing study.

12.2 Resident Fish

Returning the lower Snake River to a natural riverine environment would benefit white sturgeon by providing them additional spawning and rearing habitat and reuniting population segments ranging from McNary Dam on the Columbia River to Hells Canyon Dam on the Snake River, a stretch of 449 km (279 miles). These effects on white sturgeon need to be evaluated. We recommend that

spawning success, survival, abundance, growth, and movements of white sturgeon be monitored throughout the basin. This should be correlated with habitat changes and use.

Monitoring of smallmouth bass and northern pikeminnow populations and predation on juvenile salmonids should continue. Population responses of these two important predators to natural river drawdown would provide valuable insight to future management recommendations in the Columbia River system.

Responses such as abundance, recruitment, growth, and habitat use of both native and non-native species to the re-creation of a riverine environment should be documented. Although many native species are not considered sport fish, their presence in the lower Snake River is not only valuable, but necessary in maintaining a healthy, properly functioning ecosystem. Currently, the majority of fishing pressure for resident fish is on non-native species, particularly channel catfish, smallmouth bass, and crappies. Their population responses to changes in the environment need to be evaluated so that appropriate management can take place.

Finally, we recommend evaluation of the rainbow trout mitigation program. With changes in habitat and angler use, the prescribed mitigation may no longer be appropriate.

12.3 Invertebrates

Changes in abundance and diversity of invertebrates post-implementation should be monitored. Lower Snake River invertebrate populations are much reduced when compared with historical data. The invertebrate community plays an extremely important function in ecosystem health, and its response to removal of the four lower Snake River dams needs to be documented. Documenting the time required and the extent to which the invertebrate community recolonizes the restored habitat will provide an excellent opportunity to learn more about ecosystem functions.

Natural river drawdown is expected to restore riverine habitat conditions for aquatic insects and other invertebrates that are fed upon by juvenile salmonids and other fish. Biological monitoring should be conducted to determine the species of invertebrates that initially colonize restored riverine habitats, the types of aquatic invertebrates associated with various habitats, the rates at which various species of aquatic invertebrates colonize these habitats, species succession over time; species diversity and abundance, and use by juvenile salmonids and other fish.

12.4 Terrestrial Resources

There would be a need to monitor the losses and gains of wetlands, riparian habitats, and other habitats following a drawdown to determine if changes in management and mitigation measures are warranted. This could be accomplished through cover-typing efforts.

The effectiveness of mitigation measures should be monitored, as well as potential impacts of the mitigation measures themselves. This may best be accomplished through the use of HEP analyses at certain time intervals.

Long-term plant and animal responses to drawdown should be monitored to facilitate evaluation and understanding of long-term physical changes to habitats and certain wildlife species. This could be accomplished through the use of photopoints, aerial photos, satellite data, HEP or other habitat analyses, periodic surveys (such as those completed for the feasibility study), and documentation of data on regional GIS and other available digital information systems.

Conducting the initial measured HEP analyses and repeating the analyses every 10 years as previously agreed to, would be an excellent tool for monitoring habitat quality for Compensation Plan purposes.

The Corps has also stated, and we support the statement, that some monitoring program is needed to ensure that management techniques are applied appropriately and that habitat condition and wildlife use reach expected levels (Corps, 1997b).

12.5 Environmental Contaminants

A monitoring program should be developed to determine if resuspension or the availability of bioaccumulative contaminants are increased during the drawdown. The monitoring program should be developed in coordination with USFWS and USGS. Monitoring should address bioaccumulation and should involve a sensitive ecological receptor or use of passive sampling devices such as semipermeable membrane devices, caged mussels, or other techniques.

13. Other Recommendations

13.1 Anadromous Fish

13.1.1 Temperature Control at Brownlee Dam

Presently, Brownlee Dam does not have the capability to control the temperature of its water releases. Brownlee Reservoir stratifies in the summer and has colder water at greater depths (Ebel and Koski, 1968). If colder water could be drawn from Brownlee Reservoir, it could be used to cool water temperatures in the lower Snake River reservoirs, as well as for flow augmentation during critical summer periods when subyearling chinook are moving downstream. Temperature control could also be used during the adult migration, spawning, and incubation periods of fall chinook salmon to provide suitable conditions downstream from Brownlee Dam.

Presently, the Hells Canyon hydroelectric complex, which includes Brownlee Dam, is going through relicensing of its existing Federal Energy Regulatory Commission (FERC) license. Relicensing of this facility provides the opportunity for controlling the temperature of water released from the Hells Canyon complex by installing features such as a multilevel water withdrawal system at Brownlee Dam. Temperature control capability has been incorporated into many new dams and is being considered by the Corps in the Willamette River System at Cougar and Blue River dams. We recommend that installation of a temperature control system at Brownlee Dam be investigated in the relicensing process for the Hells Canyon Hydroelectric Complex (FERC License Number 1971) by the Idaho Power Company, state and federal fisheries agencies, Indian tribes, and other participants. If determined to be feasible, temperature control should be included as a requirement of the new license for this facility.

13.1.2 Additional Generating Capacity at Hells Canyon Dam Complex

The NMFS 1995 Biological Opinion includes a requirement that lower Snake River flows be augmented with 34,246.4 m^3 (427,000 acre feet) of water from the upper Snake River System. The water is provided from BOR operated facility. The present Corps' study will examine providing an additional 1 million acre feet of flow augmentation water from the upper Snake River. Delivery of flow augmentation water is now limited by a restriction on the volume of water that can pass the Milner hydroelectric facility and generating capacity at the Hells Canyon hydroelectric complex. The flow at Milner is limited to 120.3 m^3/s (1,500 cfs) by an agreement among the Idaho Power Company, BOR, and the USFWS. The volume of water that can be passed through the Hells Canyon hydroelectric complex is limited by the generating capacity of Hells Canyon Dam which limits water release to about 2,566.5 m^3/s (32 kcfs). Water cannot be spilled voluntarily because Idaho water quality standards for TDG cannot be exceeded and because the Bonneville Power Administration has not been willing to compensate the Idaho Power Company for lost power revenue.

Flow augmentation could be limited in the future by the restrictions on water passage at the Milner and Hells Canyon hydroelectric complex. As discussed in Section 11.1.1, the Hells Canyon hydroelectric complex is going through the FERC relicensing process. This process offers the opportunity to provide additional flow capacity by installing greater generation capacity or by installing flow deflectors or other structures to reduce TDG production. FERC requires that additional generation potential be examined during the relicensing process. It also requires that water quality certification be provided by the state water quality agency.

We recommend that the Idaho Power Company, FERC, state and Federal fisheries agencies, and other parties that are involved in the relicensing of the Hells Canyon facility examine the feasibility of installing additional generating capacity and TDG reduction measures at facility dams.

13.1.3 Water Passage at Milner

The Milner Agreement was signed in June 1996 to enable the BOR to address flow requirements of Snake River salmon and snails, both of which are listed under ESA. The agreement is in effect from 1996 to 1999 and provides salmon flow augmentation of no greater than 120.3 m^3/s (1,500 cfs) past Milner Dam, except for flood control releases. Flows greater than 120.3 m^3/s (1,500 cfs) may be provided outside of the flood control periods for USFWS research purposes, but must be negotiated with the BOR and Idaho Power Company. This agreement may be terminated by any party at any time through a written notification.

The 120.3 m^3/s (1,500 cfs) maximum flow restriction may limit the volume of water that can be delivered downstream to the Hells Canyon hydroelectric complex. Increasing this flow limit would provide more flexibility to deliver water to augment flows in the lower Snake River than is now available. Possible increases in flow should be examined to determine its feasibility and potential impacts on Snake River snails.

13.1.4 Total Dissolved Gas Control at Hells Canyon Dams

Presently, the flow capacity of the Hells Canyon Hydroelectric Complex is about 2,406.0 m^3/s (30 kcfs). Streamflows greater than this volume cause spill at these dams which results in lost power generation and increased levels of TDG in the Snake River. Spill typically can occur during the spring runoff when juvenile salmonids are migrating through the Snake downstream from the Hells Canyon reach. The hydroelectric flow capacity of the Hells Canyon dams also limits the volume of flow augmentation that can be provided downstream because any additional flow greater than 30 kcfs would cause spill.

During times when uncontrolled spill occurs, TDG levels can be much higher than Idaho standards to protect aquatic life. Installation of measures to reduce TDG production at the Hells Canyon facility would help to protect salmonids during times when flow exceeds turbine capacity or power demand.

During relicensing of the Hells Canyon facility, the Idaho Power Company, state and Federal fisheries agencies, Indian tribes, water quality agencies, and other participating parties should investigate the opportunities to reduce TDG production at facility dams. The Corps is presently studying options for reducing TDG production at the dams it operates in the lower Columbia and Snake rivers. The BOR is also studying measures to reduce TDG levels that result from spilling at Grand Coulee Dam. Efforts being made by those agencies to reduce TDG should be examined to determine if measures being studied could be applied to the Hells Canyon facilities.

13.2 Resident Fish

The desired future conditions of the lower Snake River should consider the needs of two typical native resident fish species: peamouth and bridgelip sucker. These two species, an insectivore and an omnivore, provide representation of the native riverine community present prior to impoundment. Therefore, we recommend population responses of these two species to the selected alternative be monitored. Possible population parameters to be monitored include abundance, recruitment, growth, and habitat selection.

13.3 Terrestrial Resources

Connectivity between HMUs and other important habitats should be improved, and the corridor of riparian habitat along the lower Snake River reservoirs should be increased, where practicable.

As stated before, it is important to conduct measured HEP analyses on each of the HMUs to determine more accurately how Compensation Plan mitigation is progressing and whether management actions have to be adjusted. The measured HEP analyses should be completed as soon as possible for those HMUs where development has already been completed.

Following completion of measured HEP analyses, reevaluate the criteria that HUs gained through development activities that would be fully credited to the Compensation Plan. Immediately following completion of habitat development, adjust the compensation balances accordingly.

The LOA should be amended to include additional mitigation for annualized losses because of long delays in replacing and restoring lost habitat values.

Impacts from current cattle watering corridors should be reduced by developing alternative water sources, altering corridors to protect existing woody vegetation, and reestablishing native woody vegetation, where appropriate.

Extensive riprap travel barriers should be addressed to allow passage by wildlife. Guzzlers should be placed in areas where long expanses of riprapped shoreline block access to water.

Planting and continued maintenance of non-native vegetation on HMUs should be phased out.

As an enhancement measure, more active management of shrub-steppe and grassland habitats could be initiated to restore a more native community to these habitats where degraded.

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14. Conclusions

As noted throughout this draft report, there would be both beneficial and adverse effects to anadromous and resident fish and terrestrial resources from the various alternatives. In general, the Existing Systems, Maximum Transport and Surface Bypass/Collection Alternatives would have very little effect, if any, on resident fish or terrestrial resources. However, the Natural River Drawdown Alternative would result in major changes to much of the lower Snake River and would significantly affect all species groups. The benefits to fish and wildlife resources in the area of the four lower Snake River dams from drawdown would exceed those provided by the other alternatives.

It is unlikely that the Existing Systems Alternative could improve existing conditions for migrating anadromous salmonids. Past operation of the existing system has been accompanied by a downward trend in wild Snake River salmon and steelhead. Furthermore, this alternative does not address lamprey or white sturgeon passage needs and would not benefit resident fish or terrestrial resources.

The Maximum Transport Alternative would increase the percentage of juvenile salmonids collected from the lower Snake River and transported to the lower Columbia River compared to existing operations under NMFS's 1995 and 1998 biological opinions. This increase would likely be moderate because the portion of juvenile fish that is now collected and transported is already relatively high. The Maximum Transport Alternative potentially could increase the benefits as well as the disadvantages of transportation. The major benefit would be reduced mortality of juvenile fish during transit from the lower Snake River to the release point downstream from Bonneville Dam. Adverse effects could include increased straying of returning adult fish that were transported as juveniles, increased stress, and greater delayed mortality. This alternative does not address lamprey or white sturgeon passage needs and would not benefit resident fish or terrestrial resources.

The Surface Bypass/Collection Alternative involves a prototype of a concept that is still being tested. Studies to date have not shown that it has met fish passage efficiency goals and Surface Bypass cannot achieve high fish passage efficiencies alone. This alternative would need existing or improved fish screen and bypass systems. Also, Surface Bypass/Collection would not improve migration rates or survival of juvenile salmonids in the reservoirs. Finally, this alternative is not likely to improve lamprey or sturgeon migration and would not affect resident fish or terrestrial resources.

The Natural River Drawdown Alternative would restore near natural or normative riverine ecosystem conditions to over 225 km (140 miles) of the lower Snake River. Some initial measures may be needed to help restore these conditions, while much of the restoration and maintenance of these conditions would occur naturally. Also, once established, this system would virtually maintain itself and would need little human assistance in the future, similar to the free-flowing Hells Canyon Reach of the Snake River.

The Natural River Drawdown Alternative would improve migration conditions for anadromous salmonids and other migratory fish through the area of the four lower Snake River dams, restore riverine habitat and spawning habitat for fall chinook salmon, and improve water quality. Returning the lower Snake River to a free-flowing river would benefit most resident fish native to the area, while species introduced to the system and that have capitalized on the reservoir habitat would decrease in abundance. Other non-native species that typically do well in river environments, such as smallmouth bass and channel catfish, would likely either increase or not be greatly affected. Overall,

sportfishing in the study area would be enhanced. With the restoration of a functioning riparian zone and floodplain, habitat critical for many wildlife species would develop and be maintained in the long term.

While breaching the lower Snake River dams would have some short-term adverse impacts to fish and wildlife resources, the long-term benefits would far outweigh the potential impacts. Also, some of the potential adverse impacts could be mitigated. The FWCAR includes several mitigation, monitoring, and enhancement recommendations. These would help ensure that adverse impacts are avoided, minimized, and compensated and that conditions are monitored to facilitate adaptive management. We intend to include additional information in the final FWCAR to evaluate the four alternatives within the broader context of all Hs, and we will provide our final recommendations at that time.

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16. Glossary

Alternative 1—Existing Conditions: The existing hydrosystem operations under the National Marine Fisheries Service's 1995 and 1998 Biological Opinions. The Corps would continue to increase spill and manipulate spring and summer river flows as much as possible to assist juvenile salmon and steel head migration. Juvenile salmon and steelhead would continue to pass the dams through the turbines, over spillways, or through the fish bypass systems. Transportation of juvenile fish via barge or truck would continue at its current level.

Alternative 2—Maximum Transport of Juvenile Salmon: The existing hydrosystem operations plus maximum transport of juvenile salmon, without surface bypass collectors. The number of juvenile fish transported via barge or truck would be increased to the maximum extent possible.

Alternative 3—Major System Improvements: The existing hydrosystem operations and maximum transport of juvenile salmon, but with additional major system improvements (such as surface bypass collectors) that could be accomplished without dam breaching.

Alternative 4—Dam Breaching: Natural river drawdown of the four lower Snake River reservoirs.

Anadromous fish: Fish, such as salmon or steelhead trout, that hatch in fresh water, migrate to and mature in the ocean, and return to fresh water as adults to spawn.

Behavioral guidance structure (BGS): Long, steel, floating structure designed to simulate the natural shoreline and guide fish toward the surface bypass collection system by taking advantage of their natural tendency to follow the shore.

Benthic community: Aquatic organisms and plants that live on the bottom of lakes or rivers, such as algae, insects, worms, snails, and crayfish. Benthic plants and organisms contribute significantly to the diets of many reservoir fish species.

Dam breaching: In the context of this FR/EIS, dam breaching involves removal of the earthen embankment section at Lower Granite and Little Goose, and formation of a channel around Lower Monumental and Ice Harbor.

Dissolved gas supersaturation: Caused when water passing through a dams spillway carries trapped air deep into the waters of the plunge pool, increasing pressure and causing the air to dissolve into the water. Deep in the pool, the water is "supersaturated" with dissolved gas compared to the conditions at the water's surface.

Endangered species: A native species found by the Secretary of the Interior to be threatened with extinction.

Federal Columbia River Power System: Official term for the 14 Federal dams on the Columbia and Snake rivers.

Fish guidance efficiency (FGE): Percent of juvenile salmon and steelhead diverted away from the turbines by submersed screens or other structures.

Fish passage efficiency (FPE): Portion of all juvenile salmon and steelhead passing a facility that do not pass through the turbines.

Gas bubble disease or trauma: Condition caused when dissolved gas in supersaturated water comes out of solution and equilibrates with atmospheric conditions, forming bubbles within the tissues of aquatic organisms. This condition can kill or harm fish.

Habitat management units (HMUs): 62 parcels of land scattered along the river and reservoirs that the Corps purchased and manages as mitigation for the land that was inundated as a result of the dams and reservoirs. These HMUs are managed to replace hunting, fishing, and recreation opportunities lost as a result of inundation as well as to benefit and provide for wildlife that lost habitat to inundation.

Hydrographs: A graphic representation of stage, flow, velocity, or other characteristics of water at a give point in time.

Hydrology: The science dealing with the continuous cycle of evapotranspiration, precipitation, and runoff.

Inundation: The covering of pre-existing land and structures by water.

Irrigation: Artificial application of water to usually dry land for agricultural use.

Juvenile fish transportation system: System of barges and trucks used to transport juvenile salmon and steelhead from the lower Snake River or McNary Dam to below Bonneville Dam for release back into the river; alternative to in-river migration.

Littoral zone: The shore area along a body of water, usually a lake, down to the depth of 10 meters (33 feet).

Lock: A chambered structure on a waterway closed off with gates for the purpose of raising or lowering the water level within the lock chamber so ships can move from one elevation to another along the waterway.

Lower Snake River Hydropower Project: The four hydropower facilities operated by the Corps on the lower Snake River: Lower Granite, Little Goose, Lower Monumental, and Ice Harbor.

Megawatt (MW): One million watts, a measure of electrical power or generating capacity. A megawatt will typically serve about 1,000 people. The Dalles Dam produces an average of about 1,000 megawatts.

Minimum operating pool (MOP): The bottom 0.3 m (one foot) of the operating range for each reservoir. The reservoirs normally have a 1 to 1.5 m (3-foot to 5-foot) operating range.

Mitigation: To moderate or compensate for an impact or effect.

National Environmental Policy Act (NEPA): An act, passed by Congress in 1969, that declared a national policy to encourage productive harmony between humans and their environment, to promote efforts that will prevent or eliminate damage to the environment and the biosphere, to stimulate the health and welfare of humans, to enrich the understanding of the ecological systems and natural resources important to the nation, and to establish a Council on Environmental Quality. This act requires the preparation of environmental impact statements for Federal actions that are determined to be or major significance.

Navigation: Method of transporting commodities via waterways; usually refers to transportation on regulated waterways via a system of dams and locks.

Plan for Analyzing and Testing Hypotheses (PATH): A work group of regional fisheries biologists that measure project salmon and steelhead survival rates associated with alternative actions.

Pumping stations: Facilities that draw water through intake screens in the reservoir and pump the water uphill to corresponding distribution systems for irrigation and other purposes.

Recovery: The process by which the ecosystem is restored so it can support self-sustaining and self-regulating populations of listed species as persistent members of the native biotic community. This process results in improvement in the status of a species to the point at which listing is no longer appropriate under the ESA.

Resident fish: Fish species that reside in fresh water throughout their lifecycle.

Riparian: Ecosystem that lies adjacent to streams or rivers and is influenced by the stream and its associated groundwater.

Scouring: Concentrated erosive action, especially by stream or river water, as on the outside curve of a bend.

Simulated Wells Intake (SWI): Modified turbine intake that draws water from below the surface so that the surface is calmer and juvenile fish are less influenced by turbine flows. This allows juvenile fish more opportunity to discover and enter the SBC.

Spill: Water released through the dam spillways, rather than through the turbines. Involuntary spill occurs when reservoirs are full and flows exceed the capacity of the powerhouse or power output needs. Voluntary spill is one method used to pass juvenile fish without danger of turbine passage.

Spillway flow deflectors (flip lips): Structures that limit the plunge depth of water over the dam spillway, producing a less forceful, more horizontal spill. These structures reduce the amount of dissolved gas trapped in the spilled water.

Surface bypass collection (SBC) system: System designed to divert fish at the surface before they have to dive and encounter the existing turbine intake screens. SBCs direct the juvenile fish into the forebay, where they are passed downstream either through the dam spillway or via the juvenile fish transportation system of barges and trucks.

Survival: The species' persistence beyond the conditions leading to its endangerment, with sufficient resilience to allow for potential recovery from endangerment. The condition in which a species continues to exist into the future while retaining the potential for recovery.

Threatened species: A native species likely to become endangered within the foreseeable future.

Total suspended sediment (TSS): The portion of the sediment load suspended in the water column. The grain size of suspended sediment is usually less than one millimeter (0.04 in) in diameter (clays and silts). High TSS concentrations can adversely affect primary food production and fish feeding efficiency. Extremely high TSS concentrations can impair other biological functions such as respiration and reproduction.

Turbidity: An indicator of the amount of sediment suspended in water. It refers to the amount of light scattered or absorbed by a fluid. In streams or rivers, turbidity is affected by suspended particles of silts and clays, and also by organic compounds like plankton and microorganisms. Turbidity is measured in nephelometric turbidity units.

Turbine intake screens: Standard-length traveling fish screens or extended-length submerged bar screens that are lowered into the turbine bulkhead slots to divert fish from the turbine intake.

Turbine intakes: Water intakes for each generating unit at a hydropower facility.

Wetland: An ecosystem in which groundwater saturates the surface layer of soil during a portion of the growing season, often in the absence of surface water. This water remains at or near the surface of the soil layer long enough to induce the development of characteristic vegetative, physical, and chemical conditions.

Zooplankton: Tiny, floating animals that provide a food source for larger aquatic organisms such as snails and small fish.

Annex A

Fish and Wildlife Species Found Within the Lower Snake River Study Area

Table A-1. Resident Fish Collected in the Lower Snake River

Common name (*Scientific name*)	**Native (N) or Non-native (E)**	**Abundant (A), Common (C), Locally Abundant (L) or Rare (R)**[1/]
White sturgeon (*Acipenser transmontanus*)	N	C
Mountain whitefish (*Prosopium williamsoni*)	N	R
Rainbow trout (*Oncorhynchus mykiss*)	N	C
Kokanee (*Oncorhynchus nerka*)	N	R
Brown trout (*Salmo trutta*)	E	R
Bulltrout (*Salvelinus confluentus*)	N	R
Chiselmouth (*Acrocheilus alutaceus*)	N	C
Carp (*Cyprinus carpio*)	E	A
Peamouth (*Mylocheilus caurinus*)	N	R
Northern pikeminnow (*Ptychocheilus oregonenis*)	N	C
Speckled dace (*Rhinichthys osculus*)	N	R
Redside shiner (*Richardsonius balteatus*)	N	C
Bridgelip sucker (*Catostomus columbianus*)	N	A
Largescale sucker (*Catostomus macrocheilus*)	N	A
Yellow bullhead (*Ictalurus natalis*)	E	L
Brown bullhead (*Ictalurus nebulosus*)	E	L
Black bullhead (*Ictalurus melas*)	E	R
Channel catfish (*Ictalurus punctatus*)	E	C
Tadpole madtom (*Noturus gyrinus*)	E	R
Flathead catfish (*Pylodictis olivaris*)[2/]	E	R
Sand roller (*Percopsis transmontana*)	N	R
Three-spine stickleback (*Gasterosteus aculeatus*)	N	R
Pumpkinseed (*Lepomis gibbosus*)	E	L
Warmouth (*Lepomis gulosus*)	E	R
Bluegill (*Lepomis macrochirus*)	E	L
Green sunfish (*Lepomis cyanellus*)	E	R
Smallmouth bass (*Micropterus dolomieui*)	E	A
Largemouth bass (*Micropterus salmoides*)	E	L
White crappie (*Pomoxis annularis*)	E	L
Black crappie (*Pomoxis nigromaculatus*)	E	L
Yellow perch (*Perca flavescens*)	E	L
Walleye (*Stizostedion vitreum*)	E	R
Prickly sculpin (*Cottus asper*)	N	R
Piute sculpin (*Cottus beldingi*)	N	R
Mottled sculpin (*Cottus bairdi*)	N	R

[1/] Based on data from Bennett, 1991; Bennett et al., 1983; Shively et al., 1991; and T. Dresser, USFWS, personal communication.
[2/] Collected in Ice Harbor Reservoir only.

Table A-2. Anadromous Fish Found in the Lower Snake River Study Area

Chinook salmon (*Oncorhynchus tshawytscha*)
-Snake River spring chinook
-Snake River summer chinook
-Snake River fall chinook
Snake River sockeye salmon (*Oncorhyncus nerka*)
Coho salmon (*Oncorhyncus kisutch*)
Steelhead (*Oncorhyncus mykiss*)
Pacific lamprey (*Lampetra tridentata*)
American shad (*Alosa sapidissima*)

Table A-3. Small Mammals Within the Lower Snake River Study Area

Documented species
deer mouse (*Peromyscus maniculatus*)
western harvest mouse (*Reithrodontomys megalotis*)
Great Basin pocket mouse (*Perognathus parvus*)
house mouse (*Mus musculus*)
long-tailed vole (*Microtus longicaudus*)
montane vole (*Microtus montanus*)
northern pocket gopher (*Thomomys talpoides*)
vagrant shrew (*Sorex vagrans*)
Merriam's shrew (*Sorex merriami*)
bushy-tailed wood rat (*Neotoma cinerea*)
Ord's kangaroo rat (*Dipidomys ordi*)
Species likely to be present since habitat present and documented presence in the vicinity
northern grasshopper mouse (*Onychomys leucogaster*)
Norway rat (*Rattus norvegicus*)

1/ Based on data from Rocklage and Ratti (1998), Cassidy et al. (1997), USFWS (1993), Fleming (1981), Lewke and Buss (1977), Asherin and Claar (1976), and Rickard (1960).

Table A-4. Other Mammals Within the Lower Snake River Study Area

Documented species

small-footed myotis (*Myotis ciliolabrum*)
Yuma myotis (*Myotis yumanensis*)
western pipistrelle (*Pipistrellus hesperus*)
Townsend's big-eared bat (*Plecotus townsendii*)
pallid bat (*Antrozous pallidus*)
black-tailed jackrabbit (*Lepus californicus*)
Nuttall's cottontail (*Sylvilagus nuttallii*)
yellow-bellied marmot (*Marmota flaviventris*)
Columbian ground squirrel (*Spermophilus columbianus*)
fox squirrel (*Sciurus niger*)
beaver (*Castor canadensis*)
muskrat (*Ondatra zibethicus*)
porcupine (*Erethizon dorsatum*)
coyote (*Canis latrans*)
raccoon (*Procyon lotor*)
long-tailed weasel (*Mustela frenata*)
mink (*Mustela vison*)
badger (*Taxidea taxus*)
striped skunk (*Mephitis mephitis*)
river otter (*Lutra canadensis*)
bobcat (*Lynx rufus*)
mountain lion (*Felis concolor*)
elk (*Cervus canadensis*)
mule deer (*Odocoileus hemionus*)
white-tailed deer (*Odocoileus virginianus*)
moose (*Alces alces*)
bighorn sheep (*Ovis canadensis*)

Species likely to be present since habitat present and documented presence in the vicinity

long-legged myotis (*Myotis volans*)
long-eared myotis (*Myotis evotis*)
fringed myotis (*Myotis thysanodes*)
hoary bat (*Lasiurus cinereus*)
big brown bat (*Eptesicus fuscus*)
white-tailed jackrabbit (*Lepus townsendii*)
eastern cottontail (*Sylvilagus floridanus*)
Washington ground squirrel (*Spermophilus washingtoni*)

1/ Based on data from Cassidy et al. (1997), Mack et al. (1994), Asherin and Claar (1976), McKern (1976), and S. Ackerman, Corps, personal communication.

Table A-5. Amphibians and Reptiles Within the Lower Snake River Study Area

Documented species

- long-toed salamander (*Ambystoma macrodactylum*)
- Woodhouse's toad (*Bufo woodhousii*)
- western toad (*Bufo boreas*)
- Pacific tree frog (*Hyla regilla*)
- bullfrog (*Rana catesbiana*)
- Columbia spotted frog (*Rana pretiosa*)
- Great Basin spadefoot toad (*Scaphiopus intermontanus*)
- short-horned lizard (*Phrynosoma douglassii*)
- western skink (*Eumeces skiltonianus*)
- racer (*Coluber constrictor*)
- western rattlesnake (*Crotalus viridis*)
- night snake (*Hypsiglena torquata*)
- gopher snake (*Pitouphis catenfir*)
- western terrestrial garter snake (*Thamnophis elegans*)
- common garter snake (*Thamnopohis sirtalis*)
- painted turtle (*Chrysemys picta*)

Species likely to be present since habitat present and documented presence in the vicinity

- sagebrush lizard (Sceloporus graciosus)
- ringneck snake (Diadophis punctatus)
- western fence lizard (Scleporus occidentalis)

1/ Based on data from Loper and Lohman (1998), Asherin and Claar (1976), and McKern (1976)

Table A-6. Birds Within the Lower Snake River Study Area (Species in Bold Type Are Classified as Neotropical Migratory Birds)[1/]

Documented species

common loon (*Gavia immer*) *
pied-billed grebe (*Podilymbus podiceps*) *
horned grebe (*Podiceps auritus*) *
red-necked grebe (*Podiceps grisegena*)
eared grebe (*Podiceps nigricollis*)
western grebe (*Aechmophorus occidentalis*)

American white pelican (*Pelicanus erythrorhynchos*)
double-crested cormorant (*Phalacrocorax auritus*)
great blue heron (*Ardea herodius*) *
great egret (*Ardea alba*)
black-crowned night-heron (*Nycticorax nycticorax*)

tundra swan (*Cygnus columbianus*) *
greater white-fronted goose (*Anser albifrons*)
snow goose (*Chen caerulescens*)
Canada goose (*Branta canandensis*) *
wood duck (*Aix sponsa*)
green-winged teal (*Anas crecca*) *
mallard (*Anas platyrhynchos*) *
northern pintail (*Anas acuta*) *
blue-winged teal (*Anas discors*) *
cinnamon teal (*Anas cyanoptera*) *
northern shoveler (*Anas clypeata*) *
gadwall (*Anas strepera*)
American wigeon (*Anas americana*) *
canvasback (*Aythya valisneria*)
redhead (*Aythya americana*) *
ring-necked duck (*Aythya collaris*) *
lesser scaup (*Aythya affinis*) *
harlequin duck (*Histrionicus histrionicus*) *
common goldeneye (*Bucephala clangula*)*
Barrow's goldeneye (*Bucephala islandica*)

[1/] Based on data from Rocklage and Ratti (1998), Fleming (1981), Lewke and Buss (1977), Asherin and Claar (1976), Lewke (1975), Buss and Wing (1966), and S. Ackerman, Corps, personal communication.
* Birds observed at the Lower Granite reservoir site immediately before inundation (Lewke and Buss, 1977).

bufflehead (*Bucephala albeola*) *
hooded merganser (*Lophodytes cucullatus*) *
common merganser (*Mergus merganser*)
red-breasted merganser (*Mergus serrator*) *
ruddy duck (*Oxyura jamaicensis*) *
turkey vulture (*Cathartes aura*)
osprey (*Pandion haliaetus*) *
bald eagle (*Haliaeetus luecocephalus*) *
northern harrier (*Circus cyaneus*) *
sharp-shinned hawk (*Accipiter striatus*) *
Cooper's hawk (*Accipiter cooperii*) *
northern goshawk (*Accipiter gentilis*) *
Swainson's hawk (*Buteo swainsoni*)
red-tailed hawk (*Buteo jamaicensis*) *
ferruginous hawk (*Buteo regalis*)
rough-legged hawk (*Buteo lagopus*) *
golden eagle (*Aquila chrysaetos*) *
American kestrel (*Falco sparverius*) *
merlin (*Falco columbarius*)
prairie falcon (*Falco mexicanus*) *
peregrine falcon (*Falco peregrinus*)

gray partridge (*Perdix perdix*) *
chukar (*Alectoris chukar*) *
ring-necked pheasant (*Phasianus colchicus*) *
California quail (*Callipepla californica*) *
wild turkey (*Meleagris gallipavo*)

sora (*Porzana carolina*) *
American coot (*Fulica americana*) *

killdeer (*Charadrius vociferus*) *
American avocet (*Recurvirostra americana*)
greater yellowlegs (*Tringa melanolueca*) *
lesser yellowlegs (*Tringa flavipes*)
spotted sandpiper (*Actitis macularia*) *
long-billed curlew (*Numenius americanus*)
western sandpiper (*Caladris mauri*)
least sandpiper (*Caladris minutella*) *

common snipe (*Gallinago gallinago*)
Wilson's phalarope (*Phalaropus tricolor*)
Franklin's gull (*Larus pipixcan*)

Bonaparte's gull (*Larus philadelphia*)
ring-billed gull (*Larus delawarensis*)
California gull (*Larus californicus*)
herring gull (*Larus argentatus*)
Caspian tern (*Sterna caspia*)
Forster's tern (*Sterna forsteri*)
black tern (*Chlidonias niger*)

rock dove (*Columba livia*) *
mourning dove (*Zenaida macroura*) *
barn owl (*Tyto alba*) *
western screech owl (*Otus kennicottii*) *
great horned owl (*Bubo virginianus*) *
northern pygmy-owl (*Glaucidium gnoma*)
burrowing owl (*Speotyto cunicularia*)
long-eared owl (*Asio otus*) *
short-eared owl (*Asio flammeus*) *

common nighthawk (*Chordeiles minor*) *
common poorwill (*Phalaenoptilus nuttallii*)
Vaux's swift (*Chaetura vauxi*)
white-throated swift (*Aeronautes saxatalis*)
black-chinned hummingbird (*Archilochus alexandri*) *
calliope hummingbird (*Stellula calliope*)
rufous hummingbird (*Selasphorus rufus*)

belted kingfisher (*Ceryle alcyon*) *
Lewis' woodpecker (*Melanerpes lewis*) *
downy woodpecker (*Picoides pubescens*) *
hairy woodpecker (*Picoides villosus*) *
northern flicker (*Colaptes auratus*) *

olive-sided flycatcher (*Contopus borealis*) *
western wood-pewee (*Contopus sordidulus*) *
willow flycatcher (*Empindonax traillii*) *

dusky flycatcher (*Empindonax oberholseri*)
Cordilleran flycatcher (*Empindonax difficilis*) *
Say's phoebe (*Sayornis saya*) *
western kingbird (*Tyrannus verticalis*) *
eastern kingbird (*Tyrannus tyrannus*) *

horned lark (*Eremophila alpestris*) *
tree swallow (*Tachycineta bicolor*)
violet-green swallow (*Tachycineata thalassina*) *
northern rough-winged swallow (*Stelgidopteryx serripennis*) *
bank swallow (*Riparia riparia*) *
cliff swallow (*Hirundo pyrrhonota*) *
barn swallow (*Hirundo rustica*)

black-billed magpie (*Pica pica*) *
American crow (*Corvus brachyrynchos*) *
common raven (*Corvus corvax*) *

black-capped chickadee (*Parus atricapillus*) *
mountain chickadee (*Parus gambeli*) *
red-breasted nuthatch (*Sitta canadensis*)
pygmy nuthatch (*Sitta pygmaea*)
brown creeper (*Certhia americana*) *

rock wren (*Salpinctes obsoletus*) *
canyon wren (*Catherpes mexicanus*) *
Bewick's wren (*Thryomanes bewickii*) *
house wren (*Troglodytes aedon*) *
winter wren (*Troglodytes troglodytes*) *
marsh wren (*Cistothorus palustris*) *
American dipper (*Cinclus mexicanus*)
golden-crowned kinglet (*Regulus satrapa*) *
ruby-crowned kinglet (*Regulus calendula*) *

Townsend's solitaire (*Myadestes townsendi*) *
veery (*Catharus fuscescens*) *
hermit thrush (*Catharus guttatus*)
American robin (*Turdus migratorius*) *
varied thrush (*Ixoreus naevius*) *

gray catbird (*Dumetella carolinensis*) *

American pipit (*Anthus rubescens*) *
Bohemian waxwing (*Bombycilla garrulus*)
cedar waxwing (*Bombycilla cedrorum*) *
northern shrike (*Lanius excubitor*) *
loggerhead shrike (*Lanius ludovicianus*)
European starling (*Sterna vulgaris*) *

solitary vireo (*Vireo solitarius*) *
warbling vireo (*Vireo gilvus*) *
red-eyed vireo (*Vireo olivaceus*) *
orange-crowned warbler (*Vermivora celata*)
Nashville warbler (*Vermivora ruficapilla*) *
yellow warbler (*Dendroica petechia*) *
yellow-rumped warbler (*Dendroica coronata*) *
Townsend's warbler (*Dendroica townsendi*) *
MacGillivray's warbler (*Oporornis tolmiei*) *
common yellowthroat (*Geothlypis trichas*)
Wilson's warbler (*Wilsonia pusilla*) *
yellow-breasted chat (*Icteria virens*) *

western tanager (*Piranga ludoviciana*) *
black-headed grosbeak (*Pheucticus melanocephalus*) *
lazuli bunting (*Passerina amoena*) *
spotted towhee (*Pipila maculatus*) *
American tree sparrow (*Spizella arborea*) *
chipping sparrow (*Spizella passerina*)
vesper sparrow (*Pooecetes gramineus*)
lark sparrow (*Chondestes grammacus*) *
savannah sparrow (*Passerculus sandwichensis*) *
grasshopper sparrow (*Ammodramus savannarum*)
fox sparrow (*Passerella iliaca*)
song sparrow (*Melospiza melodia*) *
Lincoln's sparrow (*Melospiza lincolnii*) *
white-crowned sparrow (*Zonotrichia leucophrys*) *
dark-eyed junco (*Junco hyemalis*) *

red-winged blackbird (*Agelaius phoeniceus*) *

western meadowlark (*Sturnella neglecta*) *
yellow-headed blackbird (*Xanthocephalus xanthocephalus*)
Brewer's blackbird (*Euphagus cyanocephalus*) *
brown-headed cowbird (*Molothrus ater*) *
Bullock's oriole (*Icterus bullockii*) *
rosy finch (*Leucosticte tephrocotis*) *
pine grosbeak (*Pinicola enucleator*)
purple finch (*Carpodacus purpureus*)
house finch (*Carpodacus mexicanus*) *
red crossbill (*Loxia curvirostra*)
pine siskin (*Carduelis pinus*) *
American goldfinch (*Carduelis tristas*) *
evening grosbeak (*Coccothraustes vespertinus*) *
house sparrow (*Passer domesticus*) *

Table A-7 Benthic Invertebrates Found in Lower Granite Reservoir During 1976 and 1977[1/]

Annelida

- Hirudinea
  - *Eropdella* sp.
- Oligochaeta
  - *Limnodrilus hoffmeisteri*
  - *Tubifex tubifex*

Amphipoda

- *Corophium* sp.
- *Hyallela azteca*

Decapoda

- *Pasifacticus* sp.

Insecta

- Plecoptera
  - *Aroynopteryx* sp.
  - *Enallgma* sp.
  - *Taeniopteryx* sp.
  - *Isogenus* sp.
- Epemeroptera
  - *Baetis* sp
  - *Caenis* sp.
  - *Epeorus* sp.
  - *Ephemerella* sp..
  - *Iephemerella sp.*
  - *Isogenus* sp.
  - *Paraleptophlebia helena*
  - Stenenema *sp.*
  - *Stenonema* sp
- Tricoptera
  - *Arthripsodes* sp.
  - *Brachycentrus* sp.
  - *Cheamatopsyche* sp.
  - *Hydropsyche* sp.
  - *Hydroptilla* sp.
  - *Polycentropus* sp.
  - *Tricorhodyes* sp.

[1/] Based on data from Dorband (1980).
Note: Both Soft and Hard Substrates were Sampled.

Coleoptera

Elmidae sp.

Diptera

Simulidae

Simulium sp.

Chironomidae

Calospectra sp.

Cardiocladius sp.

Chironomus albimunus

Chironomus attenatus

Chironomus plumosus

Chironomus pupae

Chironomus tenucaudatus

Chironomus tribelos

Chironomus sp. A

Cricotopus exilis

Cryptochironomus abvortis

Cryptochironomus darbyii

Cryptochironomus nais

Cryptochironomus pectinatellae

Cryptochironomus psittacinus

Cryptochironomus sp. A

Cryptochironomus sp. B

Cryptochironomus sp. C

Dicrotendipes modestus

Diplocladius sp

Endochironomus nigrans

Endochironomus subtens

Glyptotendipes senilis

Glyptotendipes sp. A

Goeldichironomus Holoprasinus

Microtendipes sp. A

Nannocladius sp.

Nannocladius sordens

Orthocladius sp.

Orthocladius sp. A

Paracladopelma sp.

Paralaterborniella idahoensis

Phaenospectra sp.

Polypedilum flavus
Polypedilum illinoense
Polypedilum sp. A
Procladius bellus
Rheotanytarsas exigans
Rheotanytarsas sp. A
Tanytarsus dives
Tanytarsus gregarius
Tanytarsus sp.
Tanytarsus sp. A
Tanytarsus sp. B
Tanytarsus sp. C
Zavrelia sp.
Ceretopagonidae
Chaoboridae
Mollusca
Gastropoda
Ferrissia sp.
Gyraulus sp.
Physa sp.
Pelecypoda
Corbicula manilensis
Sphaerium sp.

Table A-8 Freshwater Molluscs of the Lower Granite Reservoir, Snake River, Washington, Collected During the Test Drawdown in 1992[1/]

Mollusca	
Gastropoda	
Ancylidae	
Fisherola nuttallii (Halderman, 1841)	Shortface lanx
Ferrissia rivularis (Lea, 1856)	
Vorticifex effusa (Lea, 1856)	
Pelecypoda	
Corbidulidae	
Corbicula fluminea (Muller, 1774)	Asian clam
Unionidae	
Gonidea angulata (Lea, 1839)	Western ridged mussel
Anodonta californiensis (Lea, 1852)	California floater
Anodonta kennerlyi (Lea, 1860)	Western floater

[1/] Based on data from Frest and Johannes (1992).

Table A-9 Benthic Invertebrates in Soft-Substrate, Shallow-Water Habitats in Lower Granite Reservoir, 1994-1995[1/]

Platyhelminthes
- Turbellaria

Nemertea

Nematoda

Nematomorpha

Mollusca
- Gastropoda
- Archaeogastropoda
- Bivalvia

Annelida
- Oligochaeta
- Polychaeta
- Hirudinea

Crustacea
- Cladocera
  - Leptodoridae
    - *Leptodora kindtii*
- Ostracoda

Amphipoda
- Gammariae
  - *Corophium sp.*
  - *Corophium salmonis*
  - *Corophium spinicorne*
  - *Ramellogammarus oregonensis*
  - *Ramellogammarus ramellus*
  - *Hyalella azteca*
- Isopoda
  - *Porcellio* sp.
- Mysidacea
- Copepoda
  - Cyclopoida
  - Harpacticoida
  - Calanoida

Chelicerata
- Araneae

[1/] Based on data from Pool and Ledgerwood (1997).

Prostigmata
Ixodides
Insecta
Coleoptera
Elmidae
Collembola
Ephemeroptera
Caenidae
Caenis sp.
Ephemera sp.
Hexagenia *sp.*
Leptophlebiidae
Hemiptera
Formicidae
Lepidoptera
Sialis sp.
Plecoptera
Psocoptera
Thysanoptera
Diptera
Chironomidae
Orthocladiinae
Tanypodinae
Ceratopogonidae
Culicidae
Simuliidae
Tanyderidae
Orthoptera
Tricoptera
Psychomyiidae

Annex B

Current Distribution of Anadromous Salmonids in the Snake River Basin

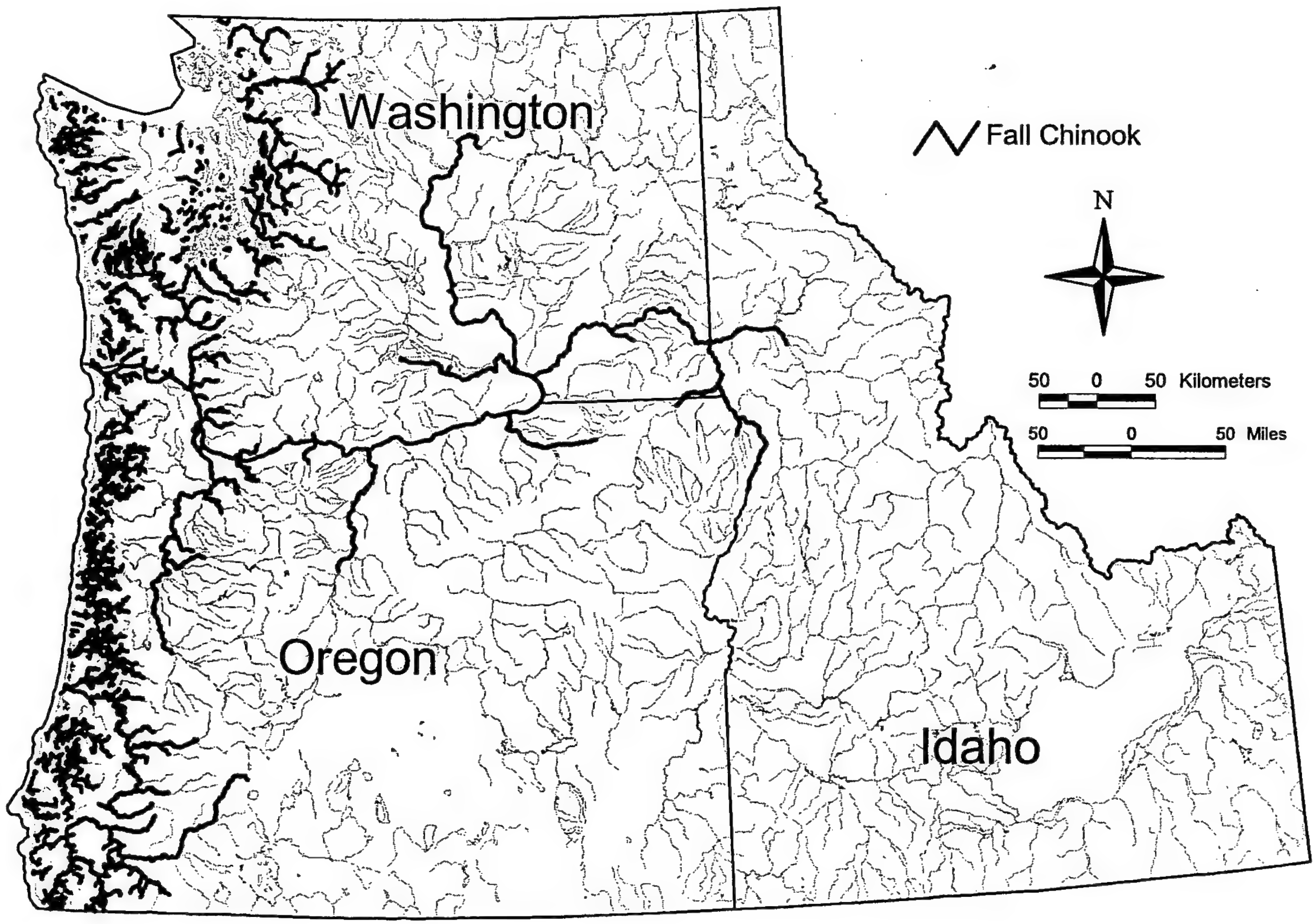

Figure A. Current Distribution of Fall Chinook Within the Snake River Basin as well as the Entire Three-State Region

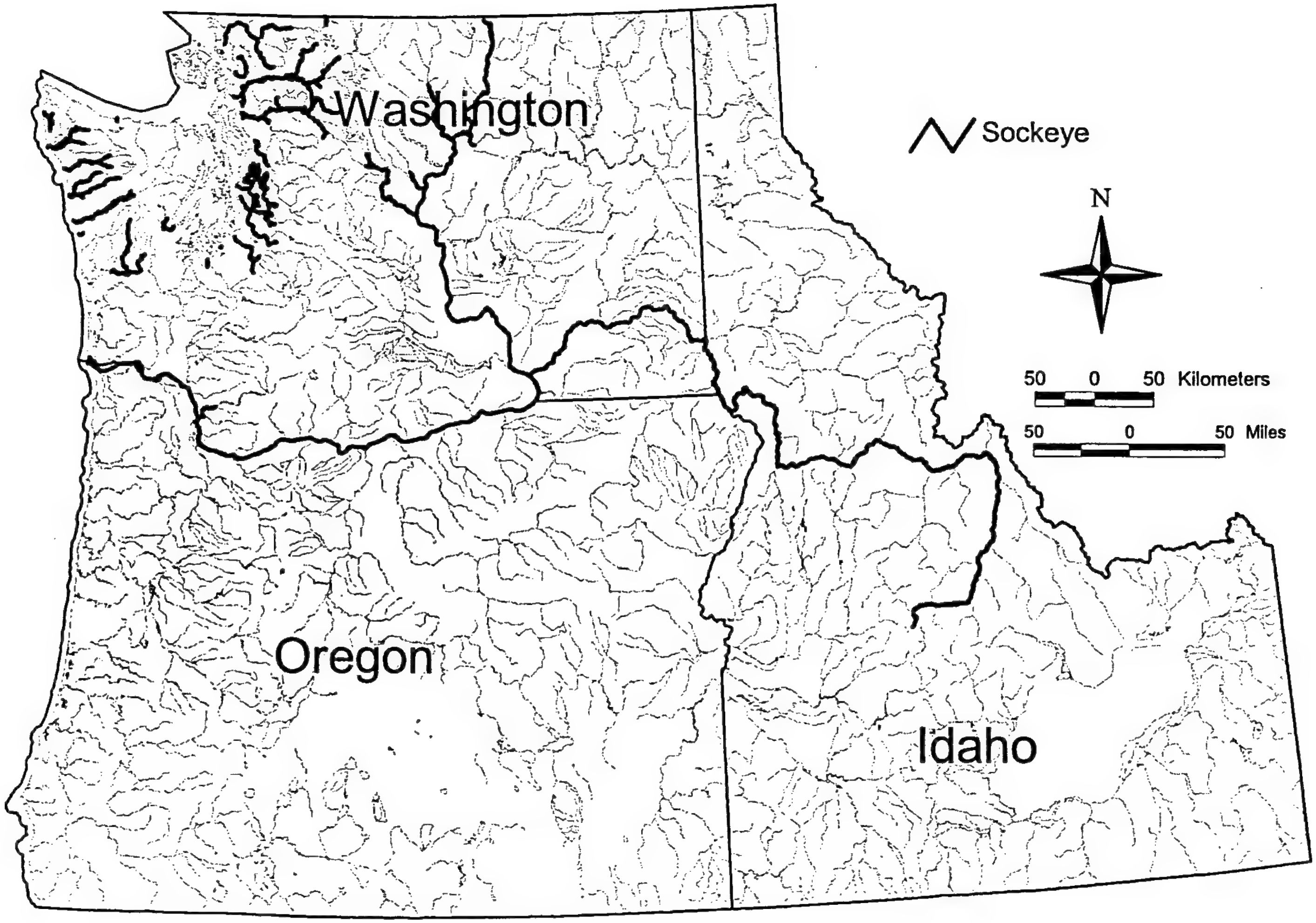

Figure B. Current Distribution of Sockeye Within the Snake River Basin as well as the Entire Three-State Region

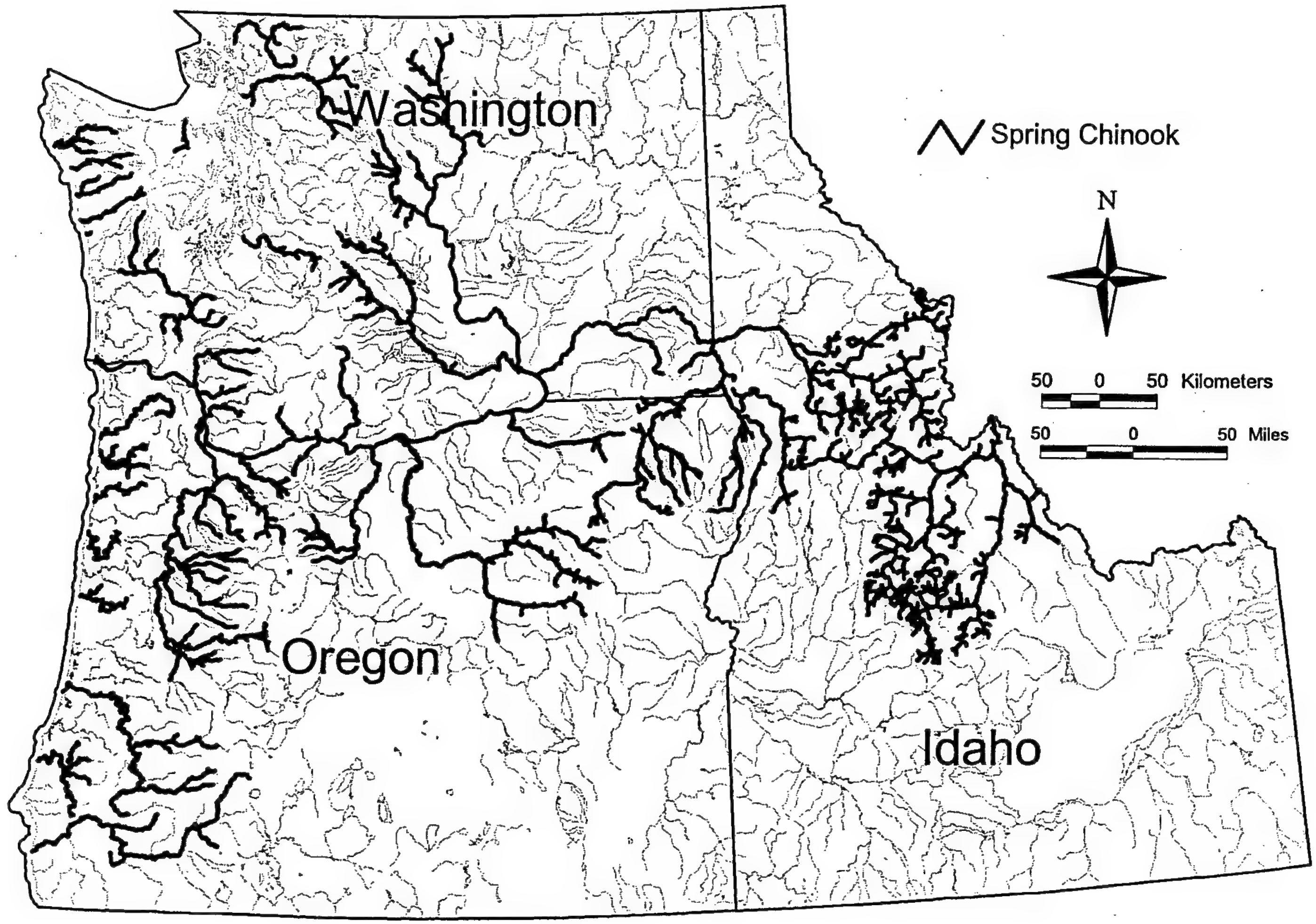

Figure C. Current Distribution of Spring Chinook Within the Snake River Basin as well as the Entire Three-State Region

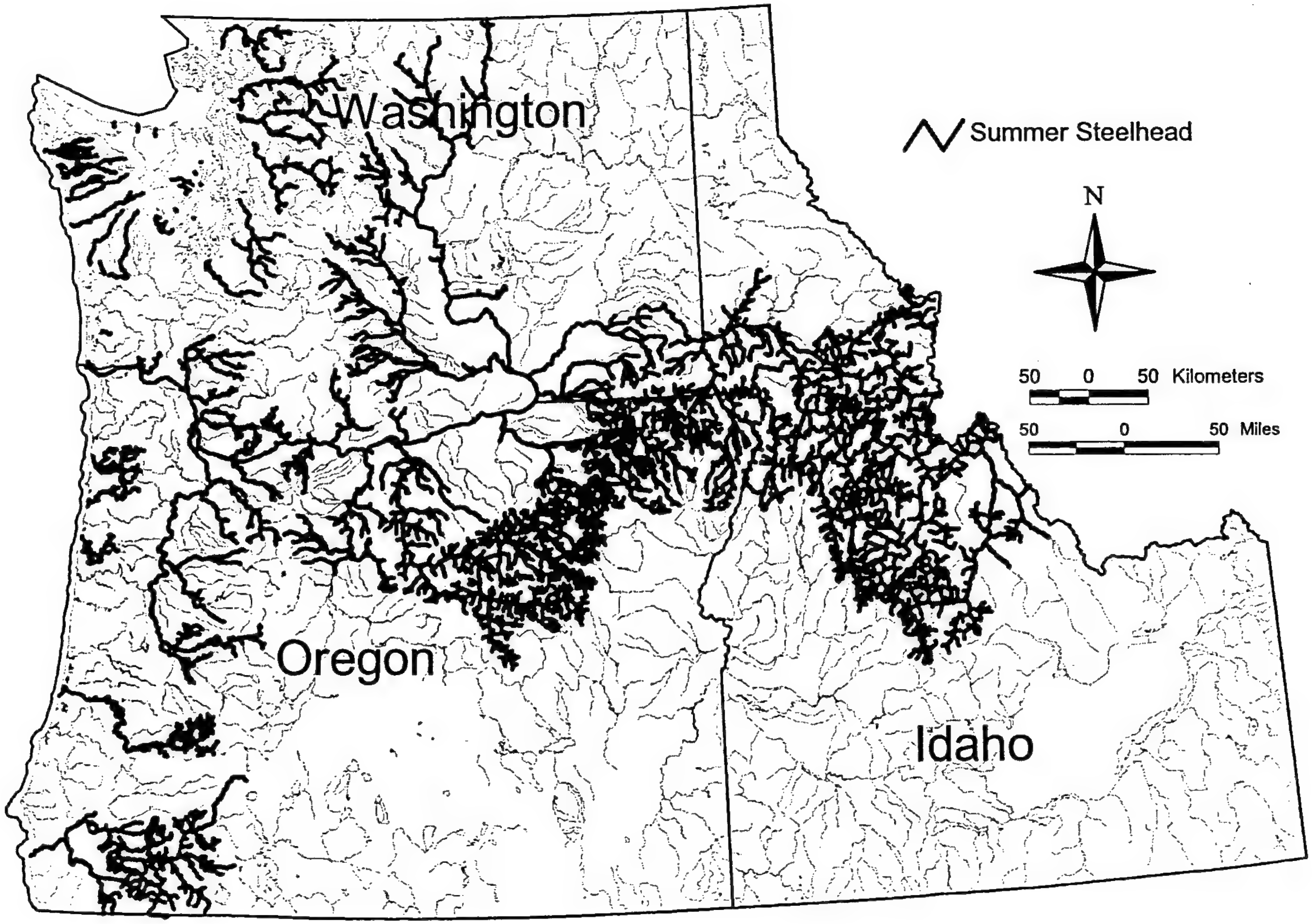

Figure D. Current Distribution of Summer Steelhead Within the Snake River Basin as well as the Entire Three-State Region

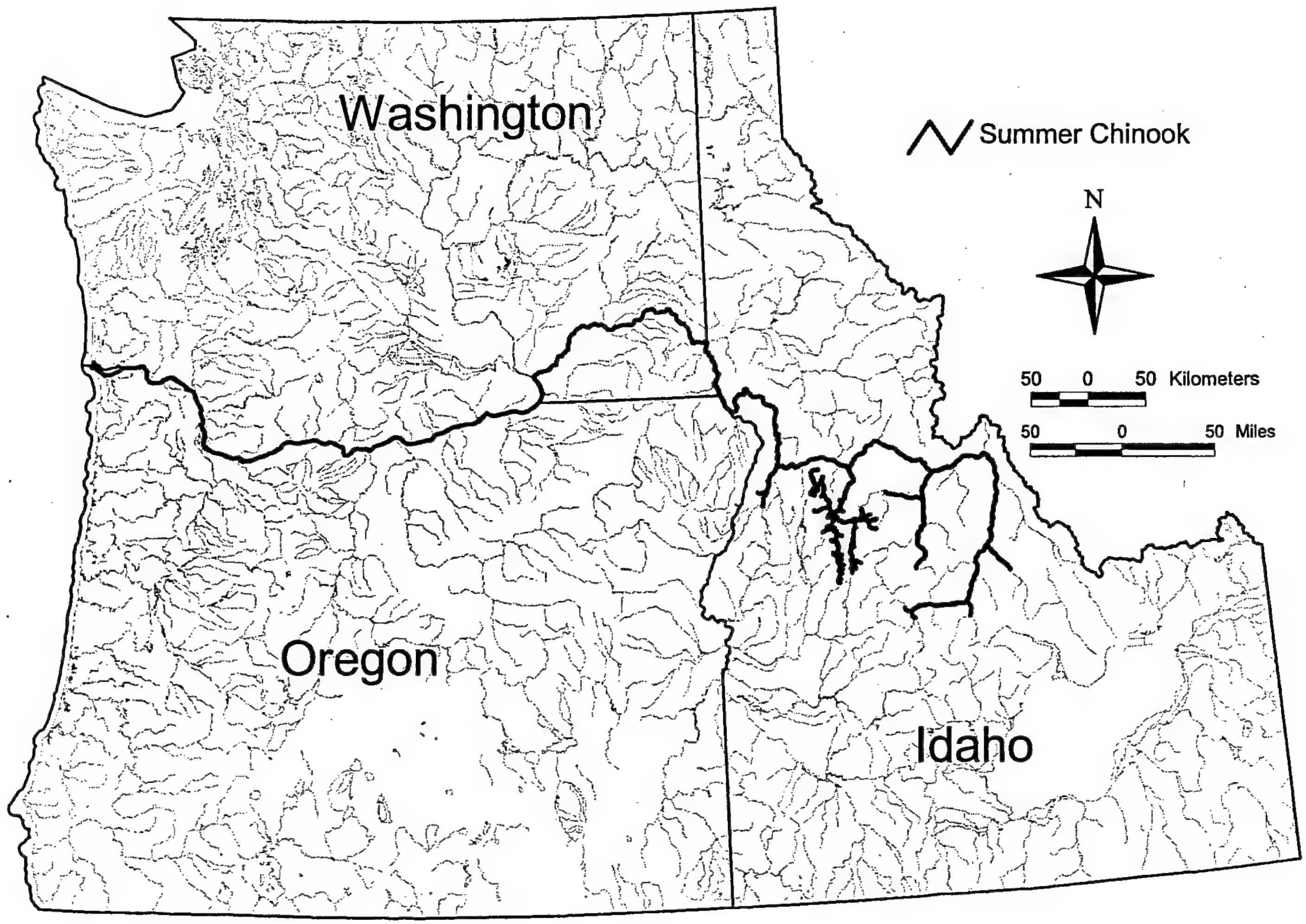

Figure E. Current Distribution of Summer Chinook Within the Snake River Basin as well as the Entire Three-State Region

Annex C

Methods Used to Estimate Projected Fall Chinook Salmon Spawning and Rearing Habitat in the Lower Snake River Under Natural River Drawdown Conditions

Spawning Habitat

The spatial distribution of habitat suitable for spawning for fall chinook salmon was estimated for the lower Snake River under natural river conditions. Suitable habitat was determined by applying spawning criteria via a geographic information system to physical characteristics of the river under a free-flowing scenario.

The physical river characteristics analyzed were water depth, mean water column velocity, and substrate. Depths and mean water column velocities that could be present under natural river conditions were generated from two-dimensional numerical hydraulic modeling done by PNNL. The simulated depth and velocity values were based on a typical low flow in August, approximately 680 m^3/s (24,000 cfs), and on riverbed elevations derived from maps drawn in 1934. Substrate information was based on the interpretation by PNNL of 1) written notations on the 1934 maps, 2) channel morphology, and 3) channel hydraulics. The dominant substrate was classified as silt-, sand, gravel, cobble+, boulder, or bedrock. When a second substrate class was present in significant amounts, a subdominant substrate was also listed. Table C-1 defines the grain size ranges for each of the substrate classes and Table C-2 lists the historic substrates interpreted for the lower Snake River. The above data has a horizontal resolution of 9.1 m (30 feet) and was provided in raster format as ARC/INFO Grids.

Table C-1. Substrate Class Definitions

Substrate class	Grain size diameter
Silt-	< 0.0625 mm
Sand	0.0625 - 2.0 mm
Gravel	2.0 - 64 mm
Cobble+	Anything > 64 mm, unless boulders were noted on historic map
Boulder	> 256 mm
Bedrock	Immeasurable

1/ Adapted from PNNL, personal communication, 1998.

The selection criteria used to determine suitable spawning habitat were based on previous studies of fall chinook behavior on the Snake River (Conner, 1994; Groves and Chandler, *in press*). The depth preferred for spawning was taken to lie between 0.4 and 6.4 m (1.3 and 21 feet), while the preferred mean column current velocity was assumed to be between 0.4 and 2.0 m/s (1.3 to 6.4 feet/s). Suitable substrate size ranged from 25 to 152 mm (1 to 6 in). To apply the substrate criteria to the available data, the preferred size range was converted to the following dominant/subdominant substrate categories: gravel, cobble, gravel/cobble, cobble/gravel, and cobble/sand.

The selection criteria were applied cell by cell using ARC/INFO software to the raster data layers of depth, velocity, and substrate. Those cells meeting all three criteria were classified as "suitable", while those failing one or more of the criteria were classified as "not suitable". For those areas where substrate information was not available because the wetted area extended beyond the substrate delineation, the habitat classification was considered "unknown" if the cells fell within the preferred ranges for both depth and velocity, or "not suitable" if they failed the depth or velocity criteria.

Table C-2. Dominant/Subdominant Substrate Classes Interpreted from Maps for the Lower Snake River, 1934

Dominant/Subdominant Substrate
Silt-/cobble+
Sand/gravel
Sand/cobble+
Gravel/silt-
Gravel/sand
Gravel/cobble+
Cobble+
Cobble+/sand
Cobble+/gravel
Cobble+/bedrock
Boulder/cobble
Bedrock
Bedrock/cobble+

Rearing Habitat

The spatial distribution of habitat suitable for rearing for fall chinook salmon was estimated for the lower Snake River under natural river conditions. Suitable habitat was determined by locating those areas where encountering juveniles would be likely given predicted physical characteristics of the lower Snake River under a natural river scenario. The likelihood of fish encounter was calculated by means of a discriminant analysis function derived from data collected on the free-flowing Hanford Reach of the Columbia River (USGS, unpublished data).

The physical river characteristics analyzed were water depth, mean water column velocity, and distance to shore. Though substrate has also been observed to be a significant environmental variable with regards to rearing habitat preference, it was excluded from this study because the available data for natural river conditions were found to lack necessary near-shore resolution.

Depths and mean water column velocities were generated from two-dimensional numerical hydraulic modeling done by PNNL. The simulated depth and velocity values were based on a typical low flow in August, approximately 24,000 cfs (680 m^3/s), and on river bed elevations derived from maps drawn in 1934. The data has a horizontal resolution of 9.1 m (30 feet) and was provided in raster format as ARC/INFO Grids by PNNL.

Distance to shore was calculated for each 9.1 by 9.1 m (30 by 30 feet) cell of the river surface using ARC/INFO software. Distance to shore was defined as the shortest linear distance from the center of a cell to a shoreline extracted from the wetted area simulated by the two-dimensional hydraulic model.

To estimate preferred rearing habitat, the separate grids of depth, velocity, and distance to shore were first exported to SAS so that the center of each cell was represented by a data point that had with it an associated depth, velocity, and distance to shore. The next step in the analysis was to reduce the data to those points that fell within 24.9 m (81.7 feet) from shore, had water depths from 0.1 to 1.6 m (0.3 to 5.3 feet), and had mean column velocities less than 1.2 m/s (4.0 feet/s). These ranges correspond to environmental conditions in which juvenile fall chinook were observed on the free-flowing Hanford Reach of the Columbia River (USGS, unpublished data), thus those points that fell outside of these ranges were classified immediately as "not suitable".

The remaining data were then run through a discriminant analysis to determine the likelihood of encountering juvenile fall chinook given values for depth, velocity and distance to shore. Habitat classified as "suitable" for rearing was defined as those points where the likelihood of encountering ten or more fish within an electrofished area was fifty percent or greater. Those points with a likelihood of encounter of less than fifty percent were classified as "not suitable". The effective area of electrofishing in the field was roughly 3 m (9 feet) in diameter (USGS, unpublished data). Results from the discriminant analysis were converted to ARC/INFO Grid format with a 9.1 m (30 feet) horizontal resolution.